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Operational Analysis—Statistical Approach

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The problem of operational analysis is covered here from the statistical point of view. Using statistics as the basic tool, the reader follows the author through the various stages of arriving at a useful quantitative business relationship—the preliminary trial and error stage of determining what specific relationships are needed and how they may be derived, crystallization of the decision on just what is to be done and how to do it, closing the job, and presenting the results to management in chart form. Limitations of statistical techniques and their use as points of departure for creative thinking are emphasized.

THE BEST BUSINESS MANAGERS can never be fully informed on what lies in the future. It is impossible to forecast or evaluate the multitude of internal and external factors that will affect business in tomorrow's environment. The achievement of American industry in spite of these limitations is a tribute to the foresight and acumen of its industrial leaders. However, the increasing complexity of business activity requires increasing assistance in the resolution of the problems it produces.

The accounting profession, and especially cost accountants, should be the principal agents in reducing industrial operational possibilities to quantitative form. To become full partners in the direction of business they must contribute dynamic analyses of management action, presented in understandable form. They should consider the static function of the record-keeper of secondary importance.

Among the questions which confront business executives, the heaviest barrage usually relates to the financial results of operations. What will be the relation between profit and volume? What volume will maintain a given profit, or what profit will result from a given volume? Where will volume and sales mixture give the greatest net return? Where is the critical or break-even area and how

A-N-Y Manufacturing Co., Inc.
CONDENSED OPERATING DATA
THREE YEARS BY MONTHS

MONTH	SALES UNITS	SALES DOLLARS (THOUSANDS)	PERCENT RETURN ON SALES (BEFORE TAXES)	PROFIT OR LOSS (BEFORE TAXES) (THOUSANDS)	TOTAL COSTS (THOUSANDS)
1	4,400	$452	7.45%	$34	$418
2	3,500	346	1.00*	3*	349
3	2,200	240	3.10*	7*	247
4	2,000	220	4.18*	9*	229
5	1,700	176	9.65*	17*	193
6	3,300	347	5.78	20	327
7	2,800	280	.20	1	279
8	3,800	386	6.01	23	363
9	3,700	378	6.40	24	354
10	3,300	332	1.20	4	328
11	3,700	377	8.20	31	346
12	3,800	380	3.10	12	368
13	5,400	550	8.00	44	506
14	5,600	567	8.80	50	517
15	4,000	410	7.40	30	380
16	5,200	538	9.00	48	490
17	4,700	484	6.60	32	452
18	3,500	377	6.00	23	354
19	2,600	253	8.85*	22*	275
20	5,100	510	7.40	38	472
21	3,900	406	4.45	18	388
22	3,700	391	5.10	20	371
23	4,000	416	6.00	25	391
24	5,800	600	9.80	59	541
25	5,100	524	6.75	35	489
26	5,000	511	5.70	29	482
27	4,100	429	2.80	12	417
28	4,300	435	3.40	15	420
29	4,700	488	5.40	26	462
30	4,500	464	5.30	25	439
31	3,100	318	4.66*	15*	333
32	3,700	385	2.60	10	375
33	4,400	463	4.30	20	443
34	4,200	430	3.90	17	413
35	4,600	476	3.10	15	461
36	4,300	444	2.10	9	435

* Indicates loss.

EXHIBIT 1

will it change with sales composition, volume, and costs? These questions are all posed in the future tense. This paper will describe one method of projecting operational analyses to provide a forward-looking answer to these questions.

This procedure is a refinement and extension of a previous investigation along similar lines. ("Today's Picture of Tomorrow's Business," Charles B. Allen, *Cost and Management*, July-August 1950). It is proposed to construct an econometric model of the operating structure of a fictitious company, estimated from previous mathematical relations, adjusting the future projection by the past trend. This technique should be generally applicable to manufacturing companies which measure operating action in either sales dollars or sales units. At least some of the principles employed should be basic to any type of economic activity.

Starting Data Assembly and Following Early Leads

For the purposes of illustrating this method, it is presumed that the reader is employed by A-N-Y Mfg. Co., Inc. The financial situation of the company has weakened in the past few years and you are asked to analyze the cause of the increasingly unsatisfactory results of its operations. In beginning the study, it is decided that unessential details of bookkeeping niceties should be ignored and an examination of the net results of operations made. It is always necessary to establish an accounting control over the analysis, to provide for subsequent inquiry into the details of broad results.

Data relating to A-N-Y Mfg. Co. Inc. is shown in Exhibit 1. A representative period must be covered to provide a range of operating patterns over expected levels of operation. The 36 monthly periods shown might be 1949 through 1951, if this is the desired structure for analysis. This data also presumes an annual two-week vacation shutdown in July. Sales dollars and sales units have been shown, although only one of these measures is required for the type analysis to be performed. The units produced are presumed to be a mixture of several hundred slightly different items, selling in different price ranges.

In beginning the investigation it is necessary to explore many possibilities before discovering leads to the most useful relationships. Many such dead-ends will accumulate as scrap in the accountant's working papers. The examination of data subsequently abandoned should not be considered unproductive. It serves to make eliminations which constructively narrow the field of possible economic relationships.

Although the workpapers will not be reproduced here, there were several comparisons of this sort, yielding negative results in A-N-Y Mfg. Co. Inc. operations. For example, scatter charts of sales prices compared to unit costs showed

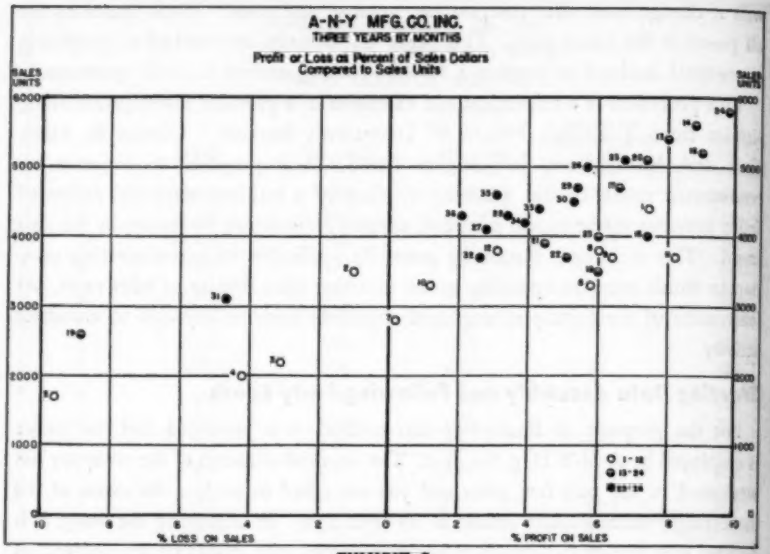


EXHIBIT 2

only random fluctuations, as did a plot of sales prices and volumes. Sales price trends were typical with a decline in late 1949, a substantial recovery to the Korea conflict in 1950, and fairly uniform averages in 1951 from O.P.S. action. There was no evidence of any seasonal trend.

Significant Relationship of Return to Volume — But What Curve?

Still another phase of the preliminary investigation contrasted net return on sales with volume. This aroused instinctive interest. The initial scatter chart of the selected data from Exhibit 1, shown on the chart offered as Exhibit 2, disclosed enough apparent relation to warrant further study. First, the mathematical method of least squares was applied to determine the average relationship between return on sales and volume according to an equation, in which X represents per cent return on sales and Y represents sales units, of the form:

$$Y = a + bX \text{ or, as calculated } Y = 3381 + 168\,X$$

This equation means that the average sales units required to produce any desired profit percentage is determined by adding the break-even volume (3381 units) to the desired percentage multiplied by 168 units. The standard error of this estimate (S_Y) is $\pm$ 558 units. The equation, with its substituted values, can be restated as:

$$X = \frac{Y - 3381}{168}$$

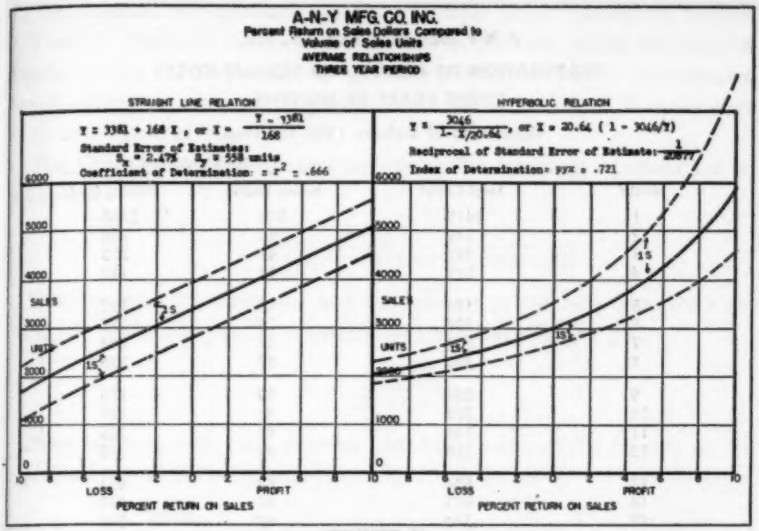


EXHIBIT 3

As so re-stated, it means that average per cent return on sales dollars is determined by dividing the difference between actual and break-even volume, or 3381 units, by a constant factor of 168 units. The standard error of this estimate is ± 2.47 per cent. Obviously the 168 in the relation is the volume in units required to produce a 1 per cent change in net profit. 3381 units is the break-even volume in units.

However, if the straight line equation is plotted on the scatter chart, Exhibit 2 (which represents the data from Exhibit 1), it does not fit well. The plotted points on the left of the average line are somewhat below it, while those on the right are above it. Perhaps another relationship will more closely approximate the relationship of return on sales to volume. Reference to other curves which might be adopted indicates that a hyperbola or a log curve should bend the straight line just the way necessary to get closer to the actual data.

In this connection, efforts to reduce the data to a linear (straight line) form to facilitate the application of the method of least squares showed that if $^1/Y$ were plotted against X, the result was linear. In other words, an inspection of a scatter chart on which $^1/Y$ was plotted against X, showed that the relationship between these two variables might reasonably be represented by a straight line. The calculation of this equation for the data given resulted in

$$^1/Y = a - bX = .0003283 - .0000159X$$

A-N-Y Manufacturing Co., Inc.

SEGREGATION OF PERIOD AND VOLUME COSTS

THREE YEARS BY MONTHS

Thousands of Dollars (000 Omitted)

Month	Total Costs*	SEGREGATION	
		Period Costs	Volume Costs
1	$418	$50	$368
2	349	45	304
3	247	47	200
4	229	42	187
5	193	41	152
6	327	38	289
7	279	31	248
8	363	37	326
9	354	39	315
10	328	43	285
11	346	41	305
12	368	48	320
13	506	53	453
14	517	49	468
15	380	42	338
16	490	51	439
17	452	48	404
18	354	52	302
19	275	39	236
20	472	46	426
21	388	48	340
22	371	42	329
23	391	47	344
24	541	49	492
25	489	49	440
26	482	47	435
27	417	53	364
28	420	48	372
29	462	52	410
30	439	51	388
31	333	47	286
32	375	51	324
33	443	55	388
34	413	53	360
35	461	56	405
36	435	51	384

* (Excludes Federal income and excess profits taxes)

From Exhibit I.

Period costs are presumed to have been determined by element (see text) and carried forward to this schedule.

Volume costs are determined by deduction of period from total costs.

EXHIBIT 4

This evaluates the constants and gives a simple linear relationship between $1/Y$ and X. However, the use of the equation in this form, which was the most convenient one for the calculation of a and b by the method of least squares, would be very inconvenient in practice, since the reciprocal of Y would have to be used instead of Y.

This difficulty may be overcome by solving the foregoing equations for Y, which gives

$$Y = \frac{1}{a - bX} = \frac{1}{.0003283 - .0000159X}$$

Dividing both the numerator and denominator of the faction on the right hand side of the equation by .0000159, the coefficient of X, we get

$$Y = \frac{62893}{20.64 - X}$$

Then, dividing both the numerator and denominator of the fraction on the right hand side of the last given equation by 20.64, we get

$$Y = \frac{3046}{1 - X/20.64} \text{ which, solved for X is } X = 20.64\left(1 - \frac{3046}{Y}\right)$$

These equations are somewhat more complicated than those first introduced ($Y = a\ bX$ and $1/Y = a - bX$), because the equations immediately above are for hyperbolas while the earlier ones are equations of straight lines (provided that the dependent variable in $1/Y = a - bX$ be considered as $1/Y$). However, the hyberbolic equations give a relationship between Y (sales units) and X (per cent return) which may be readily interpreted. It will be seen that sales units required to produce any desired profit percentage are determined above by dividing the break-even volume (3046 units) by one minus the ratio of the desired profit percentage to 20.64. Average per cent return may be determined by multiplying the constant 20.64 by a ratio that is one minus the ratio of break-even volume (3046 units) to actual volume.

It will be noted that in these latter equations, 3046 units is the break-even volume instead of the 3381 units shown before. The 20.64 is the maximum value of X, the average rate of return on sales, since the hyperbolic equation as solved for X shows that to be the asymptotic value of X when Y becomes indefinitely large. The operating structure we are working with thus places a limit of 20.64 per cent on net profit on sales, regardless of increases in volume by reason of the fact that there is a point at which unit fixed cost disappears, with a sufficiently large increase in volume.

A-N-Y Manufacturing Co., Inc.

PERIOD AND VOLUME COSTS
PER SALES UNITS AND SALES DOLLARS
THREE YEARS BY MONTHS

	PERIOD COSTS		VOLUME COSTS	
MONTH	Per sales dollar	Per sales unit	Per sales dollar	Per sales unit
1	11.1¢	$11.40	81.4¢	$83.60
2	13.0	12.90	87.9	86.90
3	19.6	21.40	83.3	90.80
4	19.1	21.00	85.0	93.50
5	23.3	24.10	86.4	89.30
6	11.0	11.50	83.3	87.50
7	11.1	11.10	88.6	88.70
8	9.6	9.70	84.5	85.70
9	10.3	10.50	83.3	85.10
10	13.0	13.00	85.8	86.30
11	10.9	11.10	80.9	82.40
12	12.6	12.60	84.2	84.20
13	9.6	9.80	82.4	83.90
14	8.6	8.80	82.5	83.60
15	10.20	10.50	82.4	84.50
16	9.50	9.80	81.6	84.50
17	9.9	10.20	83.5	86.00
18	13.8	14.90	80.1	86.30
19	15.4	15.00	93.3	90.80
20	9.0	9.00	83.5	83.60
21	11.8	12.30	83.7	87.20
22	10.7	11.40	84.1	89.00
23	11.3	11.80	82.7	86.00
24	8.2	8.40	82.0	84.80
25	9.4	9.60	84.0	86.30
26	9.2	9.40	85.1	86.90
27	12.4	12.90	84.8	88.70
28	11.0	11.20	85.5	86.60
29	10.7	11.10	84.0	87.20
30	11.0	11.30	83.6	86.30
31	14.8	15.20	89.9	92.30
32	13.2	13.80	84.2	87.50
33	11.9	12.50	83.8	88.10
34	12.3	12.60	83.7	85.70
35	11.8	12.20	85.1	88.10
36	11.5	11.90	86.5	89.30

EXHIBIT 5

It can be shown statistically that one of these relationships most nearly fits the data, or "describes" the underlying relationship, in this case, that of return on sales to volume. The coefficient of determination for the straight line equation is + .666; the index of determination for the hyperbola is + .721[3]. This indicates that 67 per cent and 72 per cent respectively, of the changes in profits or loss as a per cent of sales are "due to" or associated with changes in volume. Accordingly, the hyperbola is closer to the actual data. The log curve for this data was also calculated in the form of the equation, log Y = a + bX, but further space is not devoted here to this relation because its index of determination was smaller that than for the hyperbola.

An Underlying Fact and a Necessary Cost Classification

The equations and graphs for the straight line and the hyperbola are summarized on Exhibit 3. The curve representing the average variation of net return with volume in units has established the hyperbola as the better mathematical model of these two variables. Net return increases at an increasing rate with increasing volume. It also decreases at an increasing rate. This curve can be logically established as typical in manufacturing activity, particularly heavy industry.

But the purely statistical approach has severe limitations. It uses historical data only. The averaging process tends to freeze the operating picture instead of emphasizing its fluidity. Trends are concealed. The extent of correlation is not great enough to be useful in managerial decisions. Accordingly, this analysis must be considered as a preliminary study of the past rather than a final result in the form of a tool for use in the future.

The hyperbolic relation has a certain fascination and is surely significant. However, a little more imagination and realistic thinking is required. To paraphrase Lord Keynes, it is the amalgam of logic, intuition, and a wide knowledge of facts which may not be precise, that results in economic interpretation. Traditionally, logically, or mathematically, fixed costs are a major key to operating losses, and determine where profitable operations become unprofitable. Obviously, if all costs were variable (assuming selling price at least equalled costs) there could be no losses. Since fixed costs are constant over short periods of time, they may well be the principal factor causing profit variation. It is evident that the value of X must depend on variation of unit fixed costs with volume. Also, it is known that the curve of fixed costs per unit is a hyperbola. This looks like the fundamental underlying reason for the previously discovered hyperbolic relationship between net return and volume.

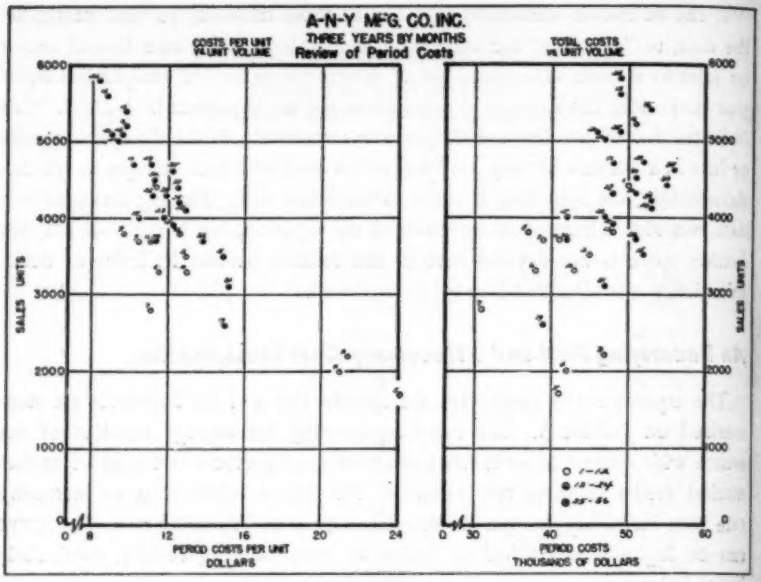

A-N-Y MFG. CO. INC.
THREE YEARS BY MONTHS
Review of Period Costs
COSTS PER UNIT vs UNIT VOLUME
TOTAL COSTS vs UNIT VOLUME
SALES UNITS
PERIOD COSTS PER UNIT DOLLARS
PERIOD COSTS THOUSANDS OF DOLLARS

EXHIBIT 6

We are not quite set to go straight ahead on this perception. Before investigating further, logic compels consideration of a classification of costs compatible with this concept—period costs and volume costs. Period costs are those which accumulate with time, and do not necessarily relate to cost accounting groupings. They may or may not be considered overhead. They must be considered from the point of view of a going concern the operations of which may fluctuate considerably and will be presumed necessary to continued operations. Without attempting to be exhaustive it may be said that period costs include all or a part of the following expenditures or accruals:

General and administrative salaries
Miscellaneous salaries and wages
Payroll taxes on applicable payrolls
Pension, compensation, welfare or group insurance
Dues and donations
Depreciation and amortization
Telephone, telegraph, teletype
Selling salaries
Vacation and holiday pay
Property, state income and franchise taxes
Fire and other necessary insurance
Legal and auditing
Rentals and royalties
Stationery, postage, office supplies
Traveling expenses
Patent amortization
Bond interest
Repairs and renewals

Exhibit 4 shows the total period costs for A-N-Y Mfg. Co. Inc., as defined above. The difference between total costs, as shown on Exhibit 1, and period

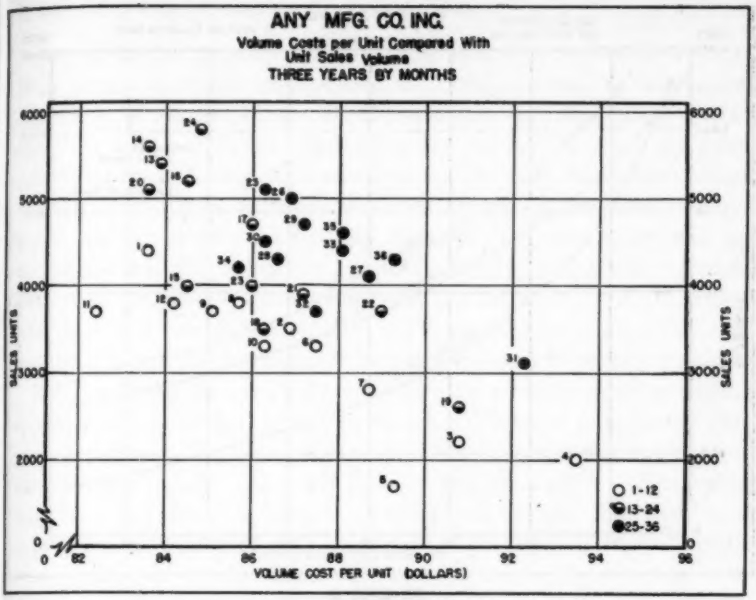


EXHIBIT 7

costs, are grouped into what is shown as volume costs on Exhibit 4. For subsequent inquiry into volume costs, Exhibit 5 shows these two cost groupings as cost per sales dollar and per sales unit.

What Study of Period Costs?

The hyperbolic behavior of costs which accumulate with time is not a new concept. However, it has not been expressed in the terms of this mathematical model. An examination of the lefthand portion of Exhibit 6 shows a definite tendency for period costs per unit to vary hyperbolically with volume, for A-N-Y Mfg. Co. Inc., as could be shown mathematically. This part of the chart should be examined in the light of the fact that the X scale from 0 to 8 has been condensed. Visualization of the chart without this condensation would show that the curve approximates the simplest form of hyperbola, which is known as an equilateral hyperbola.

The righthand portion of this chart shows total period costs plotted against volume. It should be noted that condensation of the X scale from 0 to 30 greatly accentuates the apparent amount of the variations. As would be expected, the

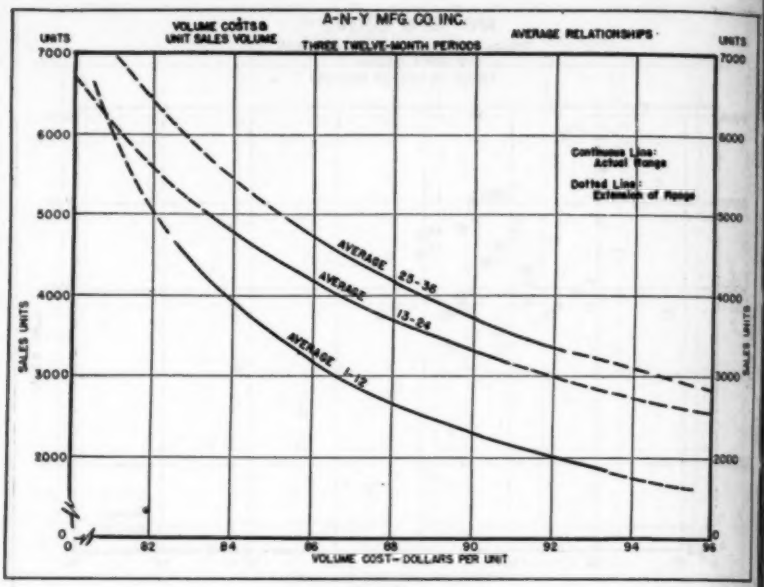


EXHIBIT 8

variations can be considered random. A further study of the chart indicates a definite progression in the level of period costs, comparing one time period with another. They appear to be increasing uniformly, regardless of volume. This may be easier to see in graphic form, than in the tabulation in Exhibit 4. Simple averaging shows the following monthly period costs for each of the three years reviewed:

Months	1 - 12	$42,000
Months	13 - 24	47,000
Months	25 - 36	51,000

It has previously been noted that period costs per unit give a definite hyperbolic relation. It has now been shown that these costs per unit and in total, show a consistently advancing trend. A little further analysis of the elements of these expenses should point the way to estimating these period costs for the next twelve months.

It will be presumed that an appropriate analysis of the period costs indicate that they should approximate $55,000 per month for a future twelve-month period. This will be used subsequently to project costs in estimating future operational possibilities. As such, it will become the keystone of the structure of an econometric model of the operating results of A-N-Y Mfg. Co. Inc.

What the Study of Volume Costs Indicates

Turning the investigation to the remaining costs, little more can be expected. If all period costs have been segregated, the remainder should be variable costs, depending on volume. However, this is not quite the case. Exhibit 7 which should be examined in the light of the fact that the variations are greatly accentuated by condensing the X scale from 0 to 82 shows volume costs per unit as tabulated on Exhibit 5, plotted against sales units. Of course, we would not expect exactly a straight line vertically down the chart, showing an equal unit volume cost regardless of volume. Nevertheless, it is surprising to note from the location of plotted points that volume costs per unit seem actually to decrease with increasing volume. The effect is not nearly so large as for period costs, but there is definitely a measurable variation, in excess of normal probability.

The reasons for this are cloudy, although there are a number of possibilities apparent. It may be due, in part, to the residual effect of incompletely segregated period costs. The most conspicuous controllable element in manufacturing costs is labor—salaries and wages paid for productive effort. When volume drops, it is very human to "stretch" six hours work to eight. Conversely, when there is a large backlog of work, there is a real possibility of achieving a little extra productivity by the simple and normal acceptance by operators of the challenge represented by work to be done. Also many of the tools, operating supplies, and other elements entering into volume costs progress in steps, rather than in direct proportion to quantities processed. The net result is that total volume costs vary with volume but at different rates for different operating ranges.

A careful examination of Exhibit 7, buttressed by the knowledge already gained of the mathematical model of manufacturing costs, is quite revealing. It shows that volume costs per unit vary with volume, decreasing with increasing volume. Also, each group of twelve monthly unit costs seems to be at a higher level, indicating an upward movement in these volume costs.

Although the mathematics involved has been eliminated from this paper, it can be shown that again the hyperbolic relation expresses the variation between unit volume costs and volume in units as shown on Exhibit 7. If volume cost were completely variable, the volume costs per unit as a function of volume would be represented by a vertical straight line. However, to the extent that fixed cost components are present, a hyperbolic function is added to the linear one, the sum of the two being hyperbolic. This is shown on Exhibit 8, interpretation of which should be tempered by the realization that the range of values for unit volume cost is very small. Here again, the steady advance of

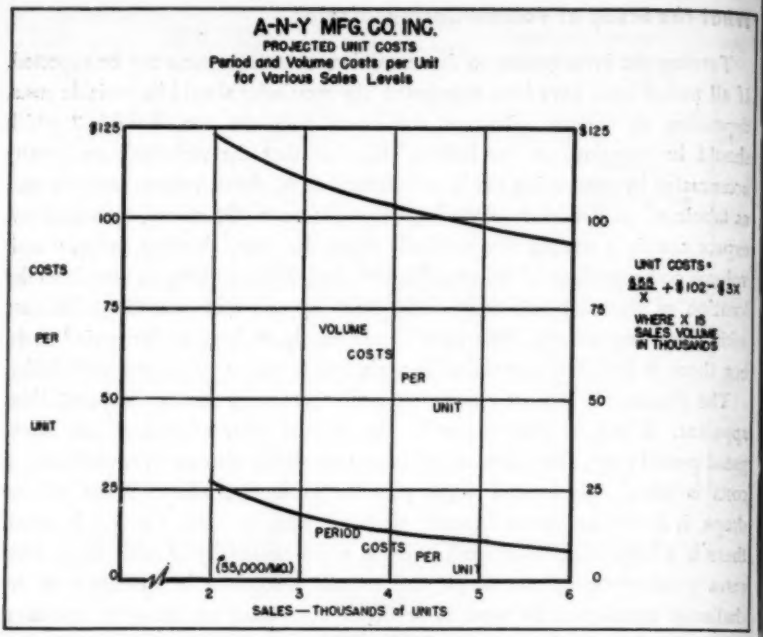


EXHIBIT 9

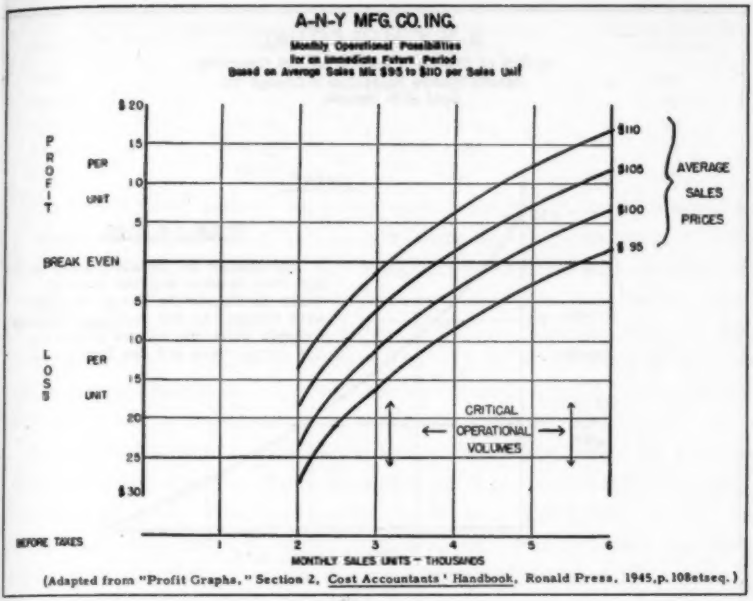
these costs can be seen from the higher level of the succeeding curves.

It is quite difficult to estimate the future trend of this group of costs. An analysis can be made of the principal elements in the cost grouping. It will be assumed that a further slight increase seems quite probable, although it is difficult to evaluate the amount. The hyperbolic form is somewhat clumsy to use, and the lack of precision in the estimate makes it unnecessary. Trial and error indicates that an appropriate volume cost per unit can be postulated by decreasing an arbitrary base cost. In this case, the expected volume costs per unit using the symbol Vu for this, may be expressed as follows:

$$Vu = \$102 - \$3 \text{ per thousand units}$$

The above is a linear equation, which is sufficiently accurate for the purpose at hand. The unit costs for various volume levels calculated from this equation, are:

VOLUME IN UNITS	UNIT VOLUME COST
2000	$96
3000	93
4000	90
5000	87
6000	84



(Adapted from "Profit Graphs," Section 2, Cost Accountants' Handbook, Ronald Press, 1945, p. 108 et seq.)

EXHIBIT 10

Cost Model, Sales Assumptions — and Two Management Tools

A projection of costs can now be made. Period costs are estimated (as indicated earlier) to be $55,000 per month. Unit period costs are thus $55 divided by sales volume in thousands. Unit volume costs, using the formula immediately above are $102 less the product of $3 and the sales volume in thousands. Total unit costs (Y) will be the sum of these two results:

$$\frac{\$55}{X} + \$102 - \$3X \text{ where } X = \text{sales volume in thousands}$$

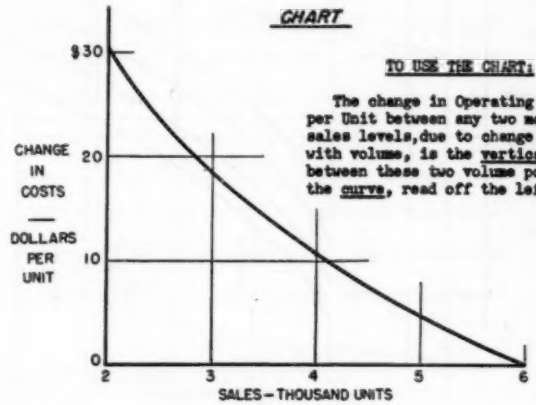
This combination results in a hyperbola $\left(Y = \frac{55}{X}\right)$ superimposed on a straight line ($Y = 102 - 3X$), the curve thus being hyperbolic. The hyperbolic nature of the curve is quite pronounced in the range considered since it is a region of high curvature. This may be readily visualized by plotting the curve from $X = 0$ to $X = 50{,}000$ units.

This can be portrayed very simply in graphic form (based on the $55,000 volume costs and the $102 value for Vu in the equation for unit volume costs) as in Exhibit 9 which summarizes the following table:

A-N-Y MFG. CO. INC.

Effect of Change in Volume on Net Operating Results (Before Taxes) Due to Change in Cost with Volume

CHART



TO USE THE CHART:

The change in Operating Results per Unit between any two monthly sales levels, due to change in cost with volume, is the vertical distance between these two volume points on the curve, read off the left scale.

TABLE

VOLUME -M UNITS	$ PER UNIT					VOLUME -M UNITS
6	30.33	18.16	10.58	4.83		6
5	25.50	13.33	5.75		4.83	5
4	19.75	7.58		5.75	10.58	4
3	12.17		7.58	13.33	18.16	3
2		12.17	19.75	25.50	30.33	2
	$ PER UNIT					
VOLUME -M UNITS	2	3	4	5	6	VOLUME -M UNITS

TO READ THE TABLE:

The change in Operating Results between any two monthly sales levels, due to change in cost with volume, is shown where the row of one of the monthly sales levels intersects the column of the other.

EXHIBIT 11

VOLUME IN UNITS	TOTAL COSTS PER 1000 UNITS	PERIOD COSTS PER 1000 UNITS	VOLUME COSTS PER 1000 UNITS
2000	$123.50	$27.50	$96
3000	111.33	18.33	93
4000	103.75	13.75	90
5000	98.00	11.00	87
6000	93.17	9.17	84

Up to this point, most of the survey work is not in a form which would be presented to management. We can now shape such a presentation. Having built a cost structure, it remains only to superimpose various sales unit mixtures resulting in different levels of average sales prices. The same analysis could be made for various profit volume ratios. In the case of A-N-Y Mfg. Co. Inc. it is presumed that these sales prices will be $95, $100, $105 and $110. This can be a pure assumption, using the historical record as a guide, or may be constructed from various product mixes in the sales pattern.

Exhibit 10 has been prepared by deducting the costs shown in the previous section of this article from the average sales prices just mentioned and plotting net profits or losses. From this chart the executives of A-N-Y Mfg. Co. Inc. can visualize a broad range of operating possibilities. It is clear that this chart relies on an underlying cost picture for the immediate future, which is known. Hence, the results of any change which management can make in its operating plans can be evaluated quite accurately.

Of course the fictitious company used as a test case in this laboratory study is not in a healthy condition. There may be several alternatives available to A-N-Y Mfg. Co. Inc. If competitive and government control conditions permit, price increases may be considered. It is the period costs—the inexorable time-cost accumulations—which have weakened the operating structure and increased the break-even point from about 50 per cent of capacity to perhaps 70 per cent, dependent on sales mix. If the increase in these costs can be checked or the costs reduced, a considerable change can be produced in net operating results.

With our new tools, however difficult and painstaking their derivation, it is only a matter of simple arithmetic to provide a relatively accurate answer to the questions raised initially. We have determined the inter-relation of costs, sales prices, volume, and profits. By substituting theoretical requirements in these mathematical equations, we can provide the answers.

Increases in volume have a very important effect on the net operating results of A-N-Y Mfg. Co. Inc. Assuming no change in average sales prices, the net change in costs with volume will be carried through directly to net operating results. This change in cost can be read from the total cost curve on Exhibit 9.

However, for management's convenience it may be preferable to re-state the relationship in the combined chart and table shown as Exhibit 11. The curve at the top of this chart is merely a replot of the total cost curve as constructed on Exhibit 9, except that zero has been substituted for the $93.17 line (cost at 6,000 units) to concentrate attention on the slope of this curve, rather than its absolute level. The table in the lower portion of Exhibit 11 shows the values between specific volume levels. These values are merely the differences in total costs for the various volumes, as shown above in the table introduced into text in connection with "construction of a cost model."

Of course, such a chart and table are not as precise as may be implied from the exactness of the amounts shown thereon. As they are based on cost projections the degree of accuracy is only relative. However, they will provide a general guide and a concrete estimate and evaluation of the underlying relation. Depending on how far the management of A-N-Y Mfg. Co. Inc. wishes to go, other similar relationships can be segregated and separately charted for executive use. Exhibit 11 is only one example of what may be done.

So That Thought Can Fly on the Wings of Fact

In essence, statistics merely symbolize real, imaginative and logical thinking. The practical application of statistics to economic problems can be effectively used by accountants without an intensive mathematical background. People who use statistics are not necessarily statisticians—applications can be made in many varied fields. However, mathematics and statistics can rarely supply a final answer to economic problems.

Logical thought will frequently modify conclusions drawn from the models constructed from the short-hand equations of mathematics. No formula will ever substitute for constructive thinking. And it is the mental struggle which acts as a catalyst for those rare flashes of intuition, crystallizing the understanding of complicated processes or, seemingly, leaping to conclusions without intermediate inferences or reasoning. (See article on Louis Bean, *Business Week*, August 18, 1951). Mathematics, as a safe point of departure in forecasting events to come, provides an anchor to unrestrained imagination.

Operations Research — A Tool of Management

by EDWARD J. THOMAS, JR.
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The cost accountant's horizon must constantly expand if he is to keep pace with progress. This calls for the study and evaluation of new tools, of which operations research is one. This paper outlines the need for it, what it is, and what it will and will not do. Its use in facilitating and predicting the effect of management decisions without usurping the functions of management is noted.

ALTHOUGH THE FORCES OF INFLATION and buying splurges have engendered tides of trade, the reports of which make pleasant reading, businessmen have become increasingly aware that their profits are shrinking. This is a danger signal, particularly since it is now apparent that the volume of business is also beginning to shrink, although the costs of doing business tend to increase. As businessmen compare their income statements with their previously prepared flexible budgets, they find some difficulty in explaining to themselves the obvious discrepancies. Somewhere along the line something went wrong. There is a growing suspicion that the earnings slump may be the procursor to a lower level of business later on.

But this is only the current aspect of the long-term problem of profit-maximization. Despite development of a number of useful control tools, there has been and still is too much intuition and too little science in the making of business decisions—and the record shows it.

In fact, return on investment for industry as a whole over a period of time, does not reveal outstanding profits. This is best indicated by the Economic Almanac published by the United States Treasury Department. This shows how much capital has been invested in the various branches of American industry and what has been the rate of return on this investment, year by year, since 1925. There is, as might be expected, a rather wide divergence in the various industries. The food, tobacco and liquor group shows an average return of about 5½ per cent, which is the largest, while the textile products group has averaged slightly over 1½ per cent. The average return for all industries is about 3.7 per cent. This is the long run picture over twenty-five years, including good times and bad, a composite national industrial profit statement. It should be remembered that in this particular quarter century a hired professional type of management has been "carrying the ball" rather than the previous owner-type of management.

Nature of and Need For Operations Research

Business publications currently report many concerns turning to an old technique with the new name of operations research, to uncover the basic patterns or operational constants which are inherent in any particular business. The managements of these concerns believe that, once these constants are known and understood, operational problems will yield to rational solution. As yet operations research is surrounded with considerable mystery, mainly because relatively few persons have developed the mathematical applications on which it is based. Nor is it properly understood that this method is not a substitute for management itself. It merely puts all the facts together in an understandable form and delimits the probabilities which may result from a combination of variable circumstances.

However, this is an important service and a proper substitute for less effective approaches. For example, management's major concern with profit and loss statements frequently proves a real detriment to analytical thinking, since it is a handy springboard for day-dreams and fanciful wishing. Companies which are losing money and should be curtailing their expenses and watching their production efficiency, can imagine themselves making it next month. Companies realizing a meagre return on their capital, can imagine themselves earning a satisfactory one. Companies earning a satisfactory return, can imagine they are getting rich. All of these companies are inclined to expand faster than they should, to relax control of costs, and generally to feel that "all's right with the world." But, by itself, the profit and loss statement simply shows how much profit or loss was incurred through operating the business over a particular period of time, not how or why. Seldom is a strictly evaluation type of analysis attempted or (more difficult) achieved, to show how the particular business operates as a money-making enterprise and to afford a clear idea of the type of controls which can be exerted at a few critical points to make it the profitable enterprise it should be.

The Approach Works in Engineering — Why Not in Management?

Sufficient evidence has long been accumulated to show that each and every business enterprise has a capacity to conform to some definite economic behavior, just as machines have certain well-defined characteristics which govern the proper operation of those machines. The electrical engineer controls the operations of electrical equipment successfully when he understands how it behaves under different conditions of use. Similarly, the mechanical engineer controls his turbine successfully when he understands the thermodynamic prin-

ciples according to which it operates. It is not different with business enterprises.

To carry the thought further, when an electrical engineer begins a study of an electrical apparatus or machine, he must first trace out the flow of electrical current through it to find out how it works or functions. His next problem is to find out why it functions. This leads him to study the principles of electrical operation throughout the apparatus and to formulate the results he observes. Usually he employs a schematic or diagram for this study, with all of the various circuits carefully traced out. Likewise, when a structural engineer designs a structure, he is confronted with known conditions of load, stress and strain. Preliminary to all else, he employs graphic diagrams in order to dispose of the members of the structure to meet these conditions. The common and well-known Maxwell diagram or polygon of resultant forces ordinarily affords him a very complete understanding of his problem.

The manager of a business can employ equally rational and analytical methods as he studies the business he must operate. His question is: "How does this business operate as a money making enterprise?" If it happens to be a textile mill, he must know, not only how it operates in the production of textiles but also how it works or functions as an economic enterprise. To do this, he can start with a diagram or schematic, as does the engineer, but, instead of dealing with specific products or forces in different physical states, he deals with values in different forms. Among these are cash, accounts receivable, machines, goods, buildings, etc. The making and understanding of such a diagram is about the most informative thing a business man can do if he wishes to come to quick grips with the problems that confront him.

The engineer possesses a very great advantage in attacking his problems, because he can utilize units of measurement that have long since been fixed as definite and unvarying standards of measurement. The businessman uses as his unit of measurement the dollar, which is far from an unvarying yardstick. Therefore, it must be borne in mind that, when we consider the economic flow sheet of a business, we must both assume that the unit of measurement—the dollar—does not change in value as it flows through the cycle and be aware that the results are distorted to the extent that this assumption is not warranted. Accountants often correct for variation in the dollar unit by use of a standard, thus eliminating price variation under study.

Examining the Mechanism by Which Profit Is Achieved

The first requirement is some straight thinking about business. To be successful, a business must render a service or furnish a product or products for which

the buying public will pay more than these cost. This means making a profit. But this simple statement becomes of utmost importance to the degree that emphasis be so shifted from the word "pay" to the word "cost." In fact, it is imperative that the emphasis be shifted if the problem is to be resolved intelligently, so that management can exert the proper forces to bring volume of sales, income, profits and costs into a harmonious and stable relationship, although it should be clearly understood that no natural relationship exists or can exist among these elements. The relationship is entirely one contrived by management and forced by management by means of controls devised for that purpose. To interpret the facts of his operation a businessman must relate them to a frame of reference, that is, he must be able to state that either correct or incorrect tendencies exist in the business and must be able to develop methods of analysis upon which sound decisions may be founded.

Many managers may feel that they do this, but one has only to look casually at any business to observe directors and officers, department heads, minor officials and even workmen deciding to do "this" and not to do "that" on a spontaneous basis which has no connection with study of operations and is certainly not centrally controlled. Yet it is the combined effect of all these decisions—the resultant forces set in motion by these decisions—which determines whether or not the business operates satisfactorily. It is interesting to hear more and more businessmen speak of taking "calculated risks," a phrase borrowed from the military. But it turns out to be a mere phrase without much meaning. As a matter of fact, most of them have not the slightest notion of how to go about calculating a risk in an actuarial sense.

In the final analysis they act on "guess" or "hunch." Since no smart professional gambler would indulge in such folly, it turns out, somewhat paradoxically, that the gambler commonly plays with the odds in his favor, while the conservative businessman merely guesses or, to put it more tactfully, makes a qualitative estimate of the effect of the variables—and hopes for the best. While the businessman's problem is inherently more complicated than the gambler's because he normally has more variables to cope with, the application of operational analysis to areas involving relatively few variables can diminish the number of instances in which purely qualitative evaluation must be resorted to.

What then, is the better way, to which this article is addressed? What are sound principles in any given case? How may one know the conditions under which a maximum probability of success can be attained? We must examine the economic mechanism by which profit is achieved. Oddly enough, the record

which gives us the economic model out of which we can discover the mechanism, is ordinarily available in every modern business. No special accounting is necessary. The asset side of the familiar balance sheet is all that is needed to trace out a process-flow diagram of how any business operates as a money-making enterprise. All the parts of the financial operation are there clearly defined, relatively and absolutely.

The Starting Point — Balance Sheet Flow and Relationship

By way of illustration, we might consider a very simple form of the asset side of a balance sheet for a manufacturing enterprise, as any accountant might set it up. Exhibit 1 lists in several figures the assets of a going concern, these assets being what the company owns or to which it has claim. For the sake of simplicity the dollar values for each item are omitted in the diagrams. This permits generalization which will afford an overall view of the mechanism in which we are interested. With a pencil we can lay in the lines of flow which make up the economic processes and can give lines their accounting names. A simple and elementary discussion of each phase will often afford more basic understanding of a business than can be gained through years of experience in it. The economic model builds itself, step by step.

In the usual operation, the first item, cash, the most liquid asset, is derived solely from accounts receivable, the money owed to the company for goods and services rendered to its customers and for which these customers have obligated themselves to pay at some future specified date. Most business is done on this basis. Line a of flow, like the other lines shown, is marked with an arrow to indicate the direction of the flow. The process by which the flow takes place is, of course, familiar. It is collection, one of the financial functions of the business, the importance of which is not always recognized, for there is nothing about it that is in any sense automatic. If the business is to enjoy health and vigor and to avoid financial stringencies, this function must be performed effectively and efficiently. Cash has been rightfully called the life-blood of business and this should never be forgotten.

But the cash collected is not long retained in its liquid form. The outflow is enormous. First, there is the outflow through the purchase of raw materials and supplies necessary to keep the business operating as represented by Line b. This line of flow is frequently generalized to the term, procurement. But such materials and supplies are not purchased simply to keep in store rooms and warehouses. Rather, they begin flowing at once into goods-in process. As goods are put into process it is necessary to apply to them labor working under the direction of management, both of which must be hired and paid for out of cash,

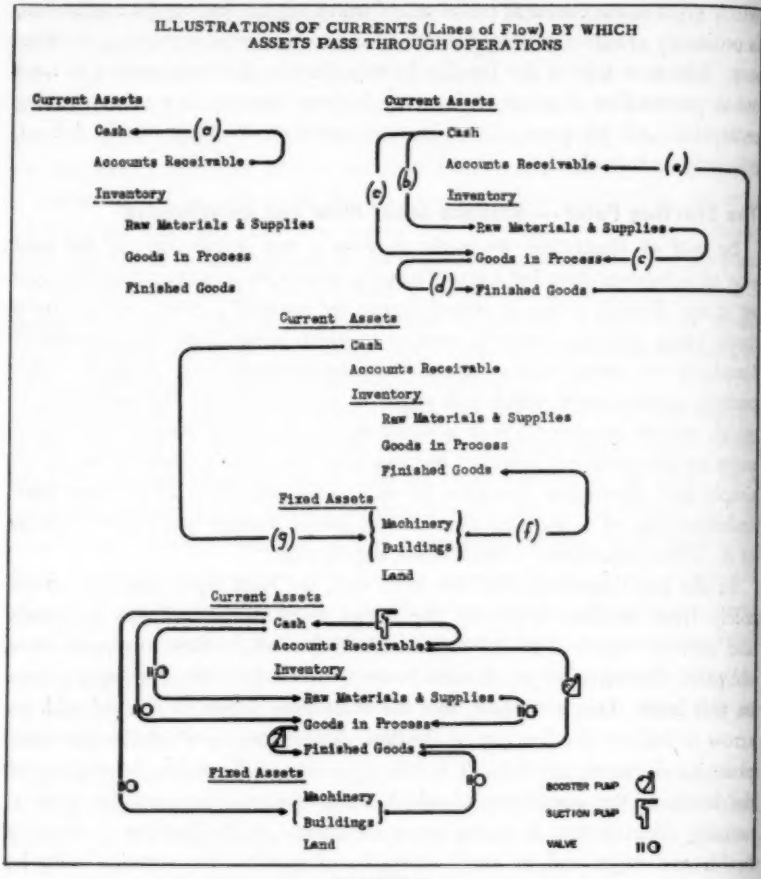

EXHIBIT 1

as shown by Line c. The process is generalized as services. Out of this combination, the flow of Line d is immediately into finished goods through the process or production.

It goes without saying that no manufacturing concern makes a product for its own sake but to fulfill the needs and wants of the customers. Thus, it immediately follows that the next logical step consists in moving the product to the customers through the process of sales or merchandising. This is disclosed in Line e. Again, there is little that is automatic in this function. It requires an astonishing amount of human effort to sell goods and any businessman knows

that his sales department is the driving force which keeps the circulation of values going. But, since sales are hardly ever made for cash, the value of the product flows into accounts receivable, thus closing the main circuit of functional flow. This simple circuit of current assets can be easily understood by anyone.

Consider now fixed assets. As a general rule, the life of machines is set at some definite time period, say ten years, and each time a unit of product is made on those machines, some small increment of the value of the machines is used up and becomes a part of the value of the product made. The buildings may have a useful life of perhaps twenty years. Here again, over each period of time, some small part of their value must be added to the value of the finished goods produced during that time period. Thus, there is a flow of value from the machinery and buildings into finished goods through the process that accountants call depreciation,—Line f stands for this flow.

The wear and tear of time and use on machinery and buildings would, if permitted to go unchecked, soon reduce these assets to such a low condition of usefulness that the operation of the plant would be greatly impaired and reduced. Consequently, repair and maintenance must be accomplished to keep these in an efficient working condition. To do this, cash must be expended and this takes place as indicated by Line g.

The Problem: Controlling to a Profitable Flow

When all of these factors are brought together it will be noted that the circuit of value-flow is by no means simple. An even and balanced flow is very difficult to evaluate even in this simple instance. It will be obvious that, when the inflow of cash exactly equals the outflow through the three major outlets, the business will exactly break even. If the inflow exceeds the outflow, it will operate at a profit, and conversely, if the outflow exceeds the inflow, a loss will be incurred. Since the objective of any business is to earn a profit the flow of values through the several circuits in the system must be controlled and directed at the critical points by the management of the enterprise. If we think of this flow of values as being fluid in nature, we can then think of control points as being a series of valves and pumps placed in the lines of flow by which executive control may be achieved. The final figure in Exhibit 1, with the pump and booster symbols, illustrates this.

The fewer the number of these controls and the more critical the points at which they are installed, the more effective the results that may be achieved and the better the management of the enterprise. This largely accounts for the fact that some concerns, although complex as to organization, are at all times under

FORMULA SOLUTION TO NEWSBOY PROBLEM

(Source Methods of Operations Research by Philip M. Morse and George E. Kimball)

By "at random", it is here meant that, in the first place, the newsboy has no regular customers who can be counted on to appear regularly, and, secondly, that as people pass him on the street, one person is as likely to buy as the next.

Now suppose that the newsboy buys k papers, and that m customers appear. If m is equal to or less than k, m papers are sold. The newsboy's profit is then $3m - 2k$. If m is greater than k, only k papers can be sold, and his profit is exactly k. His expected profit then is

$$E_k = \sum_{m=0}^{k} (3m - 2k) \frac{10^m e^{-10}}{m!} + \sum_{m=k+1}^{\infty} k \frac{10^m e^{-10}}{m!} .$$

It is easily seen that

$$E_{k+1} - E_k = \sum_{m=0}^{k} (-2) \frac{10^m e^{-10}}{m!} + \sum_{m=k+1}^{\infty} \frac{10^m e^{-10}}{m!} .$$

But, since

$$\sum_{m=0}^{\infty} \frac{10^m e^{-10}}{m!} = 1,$$

this may be written

$$E_{k+1} - E_k = 1 - 3 \sum_{m=0}^{k} \frac{10^m e^{-10}}{m!} .$$

If we imagine the newsboy buying his papers one by one, then if he has already bought k papers, he should buy the $(k + 1)$st only if $E_{k+1} - E_k$ is positive. The number he should buy is therefore the lowest number k for which $E_{k+1} - E_k$ is negative. Table 5 shows the calculation in detail, as follows:

Table 5. The newsboy problem.

k PAPERS TO BUY	$\frac{10^k e^{-10}}{k!}$	$\sum_{m=0}^{k} \frac{10^m e^{-10}}{m!}$	$E_{k+1} - E_k$ LOSSES	E_k PROFIT
0	0.00005	0.00005	0.99985	0
1	0.0005	0.0005	0.9985	0.9999
2	0.0023	0.0028	0.9916	1.9984
3	0.0076	0.0104	0.9688	2.9900
4	0.0189	0.0293	0.9124	3.9589
5	0.0378	0.0671	0.7967	4.8715
6	0.0631	0.1302	0.6094	5.6697
7	0.0901	0.2203	0.3394	6.2784
8	0.1126	0.3329	0.0013	6.6068
9	0.1251	0.4580	−0.3737	6.6195
10	0.1251	0.5831	−0.7490	6.2485
11	0.1137	0.6968	−1.0904	5.4962
12	0.0948	0.7916	−1.3748	4.4058
13	0.0729	0.8645	−1.5935	3.0310

The first column gives the values of k; the second the values of $\frac{10^m e^{-10}}{m!}$ for $m = k$; the third, the values of $\sum_{m=0}^{k} \frac{10^m e^{-10}}{m!}$; the fourth, the values $E_{k+1} - E_k$; and the last column the values of E_k. The table shows clearly that the newsboy should buy only 9 papers, and that his expected profit is 6.6 cents. If he made the obvious purchase of 10 papers, his expected profit would be 6 per cent less. In this, the losses he would incur when fewer than the expected 10 customers buy more than offset his gains if 10 or more customers come along.

EXHIBIT 2

instant control by management, while others are in constant turmoil and subject to all the storms and dislocations of the economic climate in which they operate. This makes the difference between financial stability and financial instability. As might be supposed, the more numerous and complex the controls, the more difficult it becomes to operate the enterprise. Hence the importance of holding the controls to a minimum number and critical points. Positive and direct controls under conditions of fixed individual responsibility are always to be preferred to negative and indirect controls under conditions of divided responsibility.

The final result of this effort is a process-flow diagram of how a manufacturing business operates as a profit-making enterprise. Almost any competent businessman can take his own balance sheet and in a short while trace out the economic mechanism which has been illustrated, as it applies to his own business. He will most certainly come out of such an exercise with a much clearer picture of his business than he has ever had before—a picture which is frequently viewed with something akin to shock. This far he can ordinarily go by himself. But it must occur to a thinking person that there must be some one best combination of the balance sheet factors that will be the most effective and efficient in producing adequate profits. This is definitely the case.

Few businessmen and fewer accountants are familiar enough with mathematics to set up the input-output equations which link together the various factors in the balance sheet. But such equations can theoretically be set up at each conversion point in such a manner that objectives and criteria can be established. Since sales dollars would necessarily be one of the variables in these equations, their simultaneous solution would serve to answer the vastly important question of the dollars of sales which will maximize the inflow of cash and minimize its outflow, thus netting the maximum profit, subject to the assumptions made in setting up the equations and evaluating the operational constants.

In short, by this method, it is possible to discover the operational constants that are peculiar to any individual business, and this is the special field where operations research is making its major contribution. When these constants are properly evaluated, management has criteria by which to determine not only what it achieved, but what it should have achieved if its controls had been more competently contrived and effectively used.

The Case of the Newsboy

The kind of mathematics which might be necessary can best be understood if you take the simple case of a newsboy. He is required (in our hypothetical case)

TRIAL AND ERROR SOLUTION TO THE NEWSBOY PROBLEM

Consider some alternatives in purchasing as follows:

Alternative 1 Buy 8 papers		Alternative 2 Buy 9 papers		Alternative 3 Buy 10 papers		Alternative 4 Buy 11 papers		Alternative 5 Buy 12 papers	
No. Sold	Profit Loss	No. Sold	Profit Loss	No. Sold	Profit Loss	No. Sold	Profit Loss	No. Sold	Profit Loss
12		12		12		12		12	.12
11		11		11		11	.11	11	.09
10		10		10	.10	10	.08	10	.06
9		9	.09	9	.07	9	.05	9	.03
8	.08	8	.06	8	.04	8	.02	8	-0-
7	.05	7	.03	7	.01	7	.01	7	.03
6	.02	6	-0-	6	.02	6	.04	6	.06

Consider some demand possibilities in connection with the above purchasing alternatives as follows.

Demand possibility	Average Profit for Purchasing Alternative No. 1-8 papers	No. 2-9 papers	No. 3-10 papers	No. 4-11 papers	No. 5-12 papers	Optimum Purchasing Alternative
A-10 papers demanded	.08	.09	.10	.08	.06	No. 3-10 papers
B- 9 and 11 papers demanded with equal frequency - average of 10	.08	.09	.085	.08	.06	No. 2-9 "
C-8and 12 papers demanded with equal frequency- average of 10	.08	.075	.07	.065	.06	No. 1-8 "
D-7 and 13 papers demanded with equal frequency - average of 10	.065	.06	.055	.05	.045	No. 1-8 "
E-6 and 14 papers demanded with equal frequency - average of 10	.045	.045	.04	.035	.03	No. 1-8 "

EXHIBIT 3

to buy his papers at 2 cents and sell them at 3 cents, and is not allowed to return any unsold papers. He has found from experience that, on the average, he sells 10 papers per day, with his customers appearing at random, but his sales may be more or less on any one day. His problem is, "How many papers to buy to maximize his profits?" The answer, as determined by operations research techniques, clearly indicates that the newsboy should buy only nine papers and that his expected profit is 6.6 cents. If he made the obvious purchase of ten papers, his expected profit would be 6 per cent less. In this, the losses he would incur when fewer than the ten customers buy more than offset his gain if ten or more customers come along. The formulas and calculations used by operations researchers in helping the newsboy solve his problem are shown in Exhibit 2, and are quoted from the book *Methods of Operations Research* by Philip M. Morse and George E. Kimball.

To illustrate the fact that alternative solutions to problems in operational analysis are often available, and to demonstrate that they often entail only very simple mathematics, such an alternative solution to this problem is outlined in Exhibit 3.

It will be noted from Exhibit 3 that the optimum purchase quantity may be readily calculated for any demand. The calculations assume that the demand curve is symetrical, so that frequency of demand for 10 – M papers is the same

as frequency of demand for $10 + M$. Profits are accordingly averaged for $10 - M$ and $10 + M$ without weighting. Weighting factors would, of course, be necessary if the demand curve were not symetrical.

To complete the solution of the problem, it is necessary only to have a complete demand schedule, i.e., a tabulation of the frequency with which each of the demand possibilities within the pertinent range occurs. Each demand possibility may then be weighted accordingly and the optimum number of papers to be purchased calculated.

This alternative solution involves trial and error or successive approximation. As such, it has two advantages over the mathematical method: (1) It is more readily understood by the executives and operating men who are to use the result and (2) it lends itself more readily to the compilation of tables showing results when conditions change or when a result somewhat different from the theoretical optimum is desired.

General Procedure for Employing Operations Research

The procedure for operations research, is quite similar to that used in scientific research. The subject matter is the basic difference. A general outline of procedures would be something like this:

1. Data covering past operations of a certain type must be collected. Then variations in results must be statistically correlated with the variations in details of the operation to find the approximate dependence of these results on the various operational factors involved, which may be treated as constants at one time and variables at another. Various measures of effectiveness of the operation as a whole are devised so as to discover which indicate most fully the dependence of the outcome on these operational factors and which measure the properties of the outcome that are most desirable. Continued research involves concentration on those operational factors which most markedly affect the results desired. Sometimes, at this stage, preliminary predictions which will result in improvements, can be made. Trial changes in procedure may be made and the data so obtained can be utilized to expand the interrelations and make them more definite.

2. While considerable progress has been made up to this point, the research job cannot be considered as satisfactorily completed until the dependence of the results on the various operational factors is satisfactorily explained in terms of the elements involved, such as personnel, equipment, and organization of the operation. In doing so, any of the techniques of science, mathematics, physics, biology, etc., may be used in arriving at this explanation. Subsidiary experiments, detailed mathematical analyses and laboratory measurements often are needed. After this subsequent broader study has been completed, it is possible to make more complete predictions concerning results under changing conditions. The predictions should be checked, wherever possible, by new operational experiments under controlled conditions. If the results of such experiments are successful, it is possible to state that the operation is understood and that the optimum operation can be designed for various conditions.

3. In many cases, the conclusions will indicate that certain equipment involved in the operation could be improved. The findings are turned over to the development laboratory for action. However, from the operations research viewpoint, such results are in the nature of by-products, because the basic problem is to improve operations with the equipment available at the time.

4. When several different measures of effectiveness of the operation are indicated and the choice of the best operation depends on the choice of measure, the operations research report must include an examination of the several alternatives in nontechnical language, so that top management will be in a position to make a decision. Here it must be emphasized that the problem is not completed when the details of the operation are understood by the operations research worker alone, because the purpose of the analysis is specifically to provide management with a basis for decision. This should take form in an oral briefing or a written report in terms which are nontechnical and understandable from an executive viewpoint.

5. The purpose of this reporting, be it oral or in written form, is to set forth clearly and distinctly the quantitative picture of the operation, to point out the sensitive items, and to predict changes which might bring improvements. The report should contain conclusions but, usually, should not contain recommendations. It should be designed to serve as a basis for decision but should not itself make the decisions. Although this distinction is sometimes a fine one, it is, nevertheless, most important. Obviously, the operations researcher would lose some of his freedom of action if the duties of top management were usurped and top management would lose its effectiveness if such action were allowed.

Holding to Common Sense

Thus it can be seen that operations research does not take over the decision making functions of management. Rather, it establishes a scientific method for determining in advance what effect the decisions of management will have on the earnings of the company, as well as on the stability of its financial position. Furthermore it enables the management to know the exact mathematical odds in favor of or against the desired end-results. Although many businessmen are frankly skeptical of what operations research has to offer them, more and more of them are exploring the possibility that mathematical and scientific thinking have important and growing applications to the financial conduct of their businesses.

In conclusion, we might say that operations research is a scientific method, a painstaking combination of mathematics, cost accountancy, job analysis, time and motion study, and the general integration of plant flow. Its objective is to provide executive departments with a quantitative basis for decisions regarding the operations under their control. It differs from ordinary statistical analysis in that the aim is, rather, to predict future operations and to understand them well enough so as to be able to modify them to produce new or better results.

Although the most important single mathematical tools of operations research are probability and statistical theory, numerous scientific techniques are used. It is a scientific way of never losing sight of common sense but, through adequate techniques based on rationality, to keep in sight the basic simplicity of problems in the face of the mass of detail in sight. It takes both scientific methods and a fresh objective eye to recognize the simple cure. Operations research tries to find logical sense in all the detail of which business is composed. It finds out why things happen as they do, then goes on to predicting.

Learning Curve Helps Figure Profits, Control Costs

by ROLFE WYER

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This paper evaluates the effect of learning on costs and profits in the aircraft industry. Basic relationships are explained analytically and graphically, and they are then applied to the practical problems of profit determination and control of operations. The general applicability of the technique to operations in which learning is a factor, is noted.

EVERYONE IS FAMILIAR with the learning process. It applies to every phase of our lives and hence it is not surprising that it also applies to industry. Although the phenomena is recognized in particular instances, the cost accountant has not generally considered the effect of learning in his costing methods. Perhaps the easiest way of demonstrating the point is through a graph of direct labor performance by a new operator. Exhibit 1 is such a graph. It will be noted that the various points on the graph indicate a curve of gradually improving performance and that a trend line has been interpolated among the points. In cases in which a piece rate is employed, these circumstances are usually countered by a learner's allowance. This is one of the commonly recognized cases of learning in industry. There are several other equally obvious cases, such as tooling changes, resequencing of operations, new layouts, new machines, improved design, etc.

From these considerations, a general proposition may be set forth—that the cost of every manufactured item will decrease as production continues, at a rate dependent on the types of learning which are involved in its manufacture and the effectiveness of the management concerned. A corollary to the proposition is that the extent of the cost decrease which can be anticipated is directly related to the complexity of the product and the amount of planning which is done. For example, if the operation represented on Exhibit 1 had been more carefully planned or was simple enough so that an unskilled operator could have performed it, the learning curve would not have been as steep.

Computation and Plotting of the Learning Curve

In the aircraft frame industry, the learning process has been reduced to what is called the "Curtiss 80 Per Cent Curve." This curve and variations of it are based on the theory that each time the quantity of production is doubled, the cumulative average unit labor hours will be 80 per cent (or any other percentage

from 60 to 99) of the average unit labor hours of the quantity that was doubled. In the following tabulation the cumulative average is, thus, in each case, .8 of the preceding figure, because each successive production quantity is double the preceding one:

QUANTITY OF PRODUCTION	CUMULATIVE AVERAGE UNIT LABOR HOURS
1	1
2	.8
4	.64
8	.512
16	.410

Such a reduction in labor hours may seem unduly high, but study of large volume production in the aircraft industry has proved it. The mathematical relationship between the two quantities involved may be established by letting the quantity of production — x and the cumulative average unit labor hours — y. Both x and y increase in geometric progression, since any given term is obtained by multiplying the preceding term by a constant factor. Each term of x is obtained by multiplying the preceding term by 2 and each term of y by multiplying the preceding term by .8.

It may be shown algebraically that the relationship between log y and log x would be linear, but plotting the values on log-log paper establishes this fact more simply. An inspection of such a log-log plot indicates that the slope of the line is given by

$$k = \frac{\log y_2 - \log y_1}{\log x_2 - \log x_1}$$

If $y_1 + y_2$ and $x_1 + x_2$ are set so that $y_2 = .8y_1$, and $x_2 = 2x_1$, this reduces to

$$k = \frac{\log .8}{\log 2} = \frac{1}{\log 2}(\log .8) = 3.32\ (\log .8) = -.332$$

It is thus shown that the slope of the line on the log-log plot is given by $k = 3.32 \times \frac{\log P}{100}$, where P = the percentage change in cumulative average unit hours, which is 80 per cent in the example selected.

The above material is given for the purpose of explaining the basic relationships involved. Since the illustrative figures constitute a regular series, the curve may be drawn by plotting two points on a log-log plot plus whatever additional ones may be considered necessary for checking. The slope of the curve may be determined graphically.

Any such learning curve, whether it be 80 per cent, 85 per cent, or 90 per cent, can be plotted as a straight line on log-log graph paper. Exhibit 2 is a plot based upon actual labor hour figures. It will be noted that there, the curve which has been plotted for the cumulative labor hours is an 82

PERFORMANCE OF A NEW OPERATOR
Average Daily Time per Operation
HOURS
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
Cumulative Quantity of Production
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

EXHIBIT 1

per cent curve. This was determined by plotting the various points, interpolating a line through these points, and then reading cumulative labor hours at 100 units of production and again at 200 units of production as set forth below.

$$\begin{aligned} 100 \text{ units} &= 1{,}000 \text{ hours} \\ 200 \text{ units} &= 820 \text{ hours} \\ \frac{820}{1{,}000} &= 82\% \end{aligned}$$

Care should be taken to select points on the graph which are far enough apart to minimize inaccuracy.

Also on Exhibit 2, it will be noted that a unit labor hours line has been drawn on the same plane as the cumulative unit labor hours line. It is a characteristic of these curves that, if the slope of the curve is known, conversion can be made from cumulative figures to unit figures or vice versa. The following is a table of factors by which these conversions may be made:

FACTORS FOR CONVERSION OF CUMULATIVE FIGURES TO UNIT FIGURES

Percentage of curve	Factor	Percentage of curve	Factor
60	.27	85	.77
70	.49	88	.80
75	.59	90	.85
80	.68	92	.87
82	.70	95	.93

In this case the cumulative average unit labor hours at 200 units were multiplied by the factor (820 x .70) to determine the unit labor hours, which equal 574. The unit line represents hours for a given single unit of production and thus is not an average. Since actual data is not always accumulated in this way, plotting of the line must be done by averaging. The points plotted in Exhibit 2 are set halfway between the actual readings of labor hours to date, in conformance with this fact. The unit hours line is not valid where the dotted line is shown, since the conversion factors given above were computed on the assumption that the production volumes in question would be fairly large.

Further information on this and other types of learning curves may be found in the two articles, "Projecting labor loads in Aircraft Production" (*Aero Digest*, October 1943) and "The Learning Curve," (*Western Industries*, September 1952). For the cost accountant, the important factor about learning curves is that they represent a systematic way of charting the learning phenomena and, hence, open the door to new costing techniques.

Using the Learning Curve to Determine Monthly Gross Profits

It is a normal practice in many industries to accumulate the cost of the so-called "starting load" related to a particular contract or job and to amortize

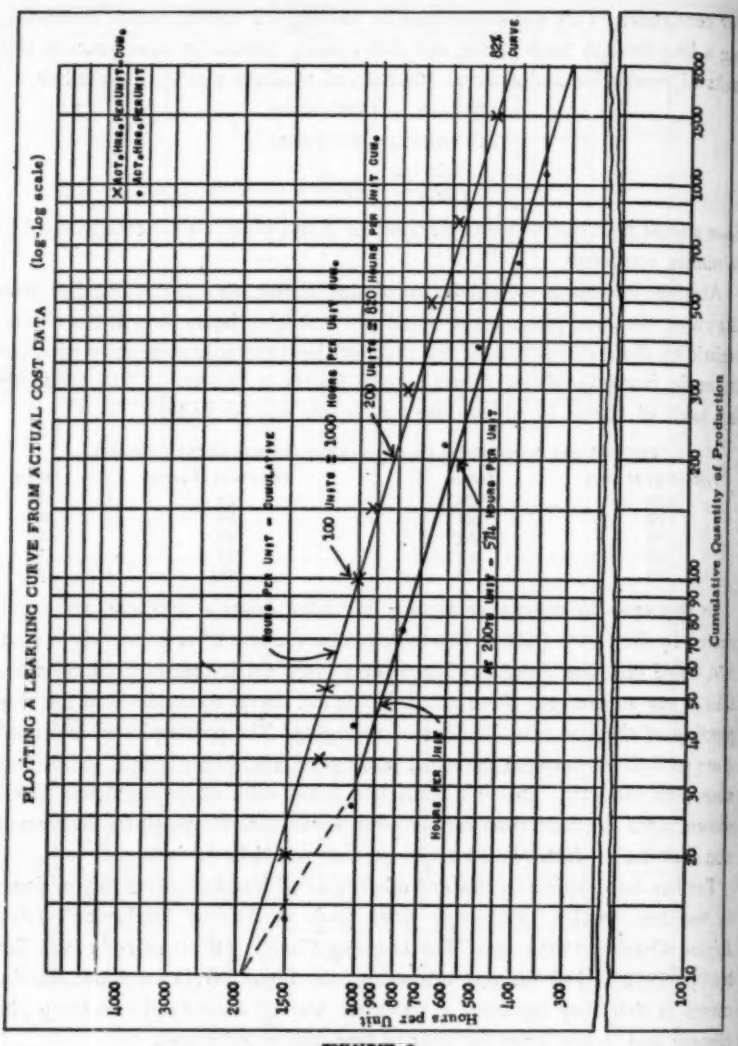

EXHIBIT 2

such costs over the life of a given production contract. Such an amortization is made because the starting load is believed to apply to all the units which are to be produced and, hence, the true and competitive cost can be determined only by such a technique. Generally, only selected items in the starting load are set up

for such an amortization, the principal ones being tooling and engineering. In the aircraft industry, the concept is extended to the point at which all of the high starting costs on a production job are averaged with the low costs anticipated after quantity production has been reached. Thus, the unit cost which is applied to each month's production, remains constant, unless deviations from the original job estimate are found.

In the beginning, this costing technique was adopted because there were no interim actual costs available. However, it should not be lightly dismissed as a poor substitute for actual costs.

Let us take an example of how the technique works when actual costs are available. The XYZ Manufacturing Company receives an order for 2,000 exhaust cones to be made over a period of one year, with a maximum production rate of 250 units per month. The selling price is set at $995 per unit, based upon a cost estimate of $850 per unit. This cost estimate is broken down as follows:

Raw material	$350
Direct labor (100 hours)	175
Overhead	325
Total	$850

The estimate for direct labor took into consideration an 80 per cent learning curve as shown in Exhibit 3. It will be noted that the cumulative unit labor hour line passes through 100 hours per unit at 2,000 units and also that a unit labor hours line was drawn below the cumulative line. This line indicates that, at the time the contract is completed, the unit labor hours will be 68. The estimating department determined the slope of this curve from prior experience on similar products.

The cost department utilizes the curve as the basic instrument for establishing the unit cost of the products shipped each month. The production schedule for each of the ten months in which shipments occurred, the actual hours as shown by the cost records for each month, and the hours applied to cost of sales based on the learning curve, are shown in the tabulation below:

ADJUSTMENT OF LABOR HOURS TO RECOGNIZE THE LEARNING CURVE IN CHARGING COST OF SALES

	UNITS SHIPPED		ACTUAL HOURS PER UNIT		CUMULATIVE HOURS PER UNIT PER LEARNING CURVE	CORRECTION OF HOURS REQUIRED		UNIT HOURS USED FOR MONTHLY COST OF SALES
Month	Monthly	Cumulative	Monthly	Cumulative		Unit	Cumulative	
1	25	25	460	460	415	45	1,125	145
2	75	100	260	310	270	40	4,000	138
3	150	250	168	225	195	30	7,500	123

ESTIMATED LEARNING CURVES - EXHAUST CONES (log-log scale)
Hours per unit
500
400
300
200
150
100
90
80
70
60
50
435
270
TOTAL HOURS PER UNIT - CUMULATIVE
395
325
297
275
256
245
TOTAL HOURS PER UNIT
TOTAL STANDARD TIME PER UNIT
125
116
110
100
68
10
25
100
250
500
750
1000
1250
1500
2000
Cumulative Quantity of Production

EXHIBIT 3

4	250	500	125	175	155	20	10,000	110
5	250	750	115	155	137	18	13,500	114
6	250	1,000	75	135	125	10	10,000	86
7	250	1,250	85	125	116	9	11,250	105
8	250	1,500	77	117	110	7	10,500	97
9	250	1,750	75	111	104	7	12,250	107
10	250	2,000	79	107	100	7	14,000	107

Estimated cumulative labor hours shown in the tabulation can be noted in Exhibit 3. Cumulative correction is calculated in the above table by multiplying units shipped to date by the difference between actual and learning curve to-date hours. The result of this multiplication shows in the next to the last column. In the final column, the labor hours used in costing the month's sales are determined by the following formula:

$$\text{Cumulative hours per unit for the total contract per the estimated learning curve} \quad \text{plus} \quad \frac{\text{Cumulative correction current month} \quad \text{less} \quad \text{Cumulative correction prior month}}{\text{Number of units shipped during the month}}$$

An example of this calculation for the figure for the second month, as shown in the table, is as follows:

$$100 + \frac{4{,}000 - 1{,}125}{75} = 138$$

A comparison of the gross profit results which may be shown for the same operations by the learning curve and actual cost methods on cost of sales is tabulated below:

MONTHLY GROSS PROFITS OVER PERIOD OF CONTRACT — LEARNING CURVE VS. ACTUAL COST METHODS

	TOTAL SALES		GROSS PROFIT — LEARNING CURVE METHOD		GROSS PROFIT — ACTUAL COST METHOD		CUMULATIVE DIFFERENCE
Month	Monthly	To date	Monthly	To date	Monthly	To date	Learning curve over actual
1	24,875		(2,000)		(41,374)		39,375
2	74,625	99,500	(3,375)	(5,375)	(49,125)	(90,500)	85,125
3	149,250	248,750	4,500	(875)	(29,250)	(119,750)	118,875
4	248,750	497,500	23,750	22,875	5,000	(114,750)	137,625
5	248,750	746,250	18,750	41,625	17,500	(97,250)	138,875
6	248,750	995,000	53,750	95,375	67,500	(29,750)	125,125
7	248,750	1,243,750	30,000	125,375	55,000	25,250	100,125
8	248,750	1,492,500	40,000	165,375	65,000	90,250	75,125
9	248,750	1,741,250	27,500	192,875	67,500	157,750	35,125
10	248,750	1,990,000	27,500	220,375	62,625	220,375	—

It is clear that the costs reported under the two methods are substantially different during virtually every month of production. For the sake of simplicity, material costs and burden rate per hour were kept constant in the calculation, but necessary corrections to these items would not have materially altered the results.

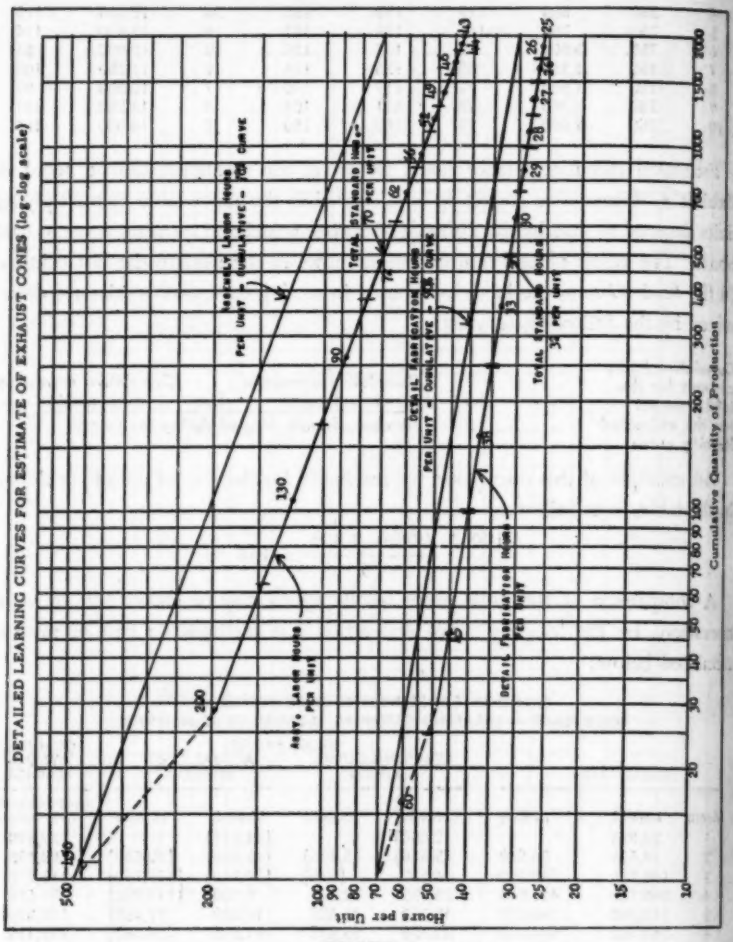
DETAILED LEARNING CURVES FOR ESTIMATE OF EXHAUST CONES (log-log scale)
Hours per Unit
Cumulative Quantity of Production
Assembly Labor Hours per Unit - Cumulative - 70% Curve
Total Standard Hours per Unit
Detail Fabrication Hours per Unit - Cumulative - 95% Curve
Total Standard Hours per Unit
Assy. Labor Hours per Unit
Detail Fabrication Hours per Unit

EXHIBIT 4

The inevitable conclusion is that, if the learning process is accepted as a fact of business life, such a technique is essential to measure the effectiveness of management on a short-term basis, whether it is applied to the books of account or not. For example, if the fiscal year had closed after the fourth month of production, actual costs to date would have been $114,750 in excess of selling price or 23.1 per cent. However, the learning curve method shows a gross profit of $22,875 or 4.6 per cent. Such a mis-statement, if applicable

to a large segment of the company's business, could have resulted in the removal of key executives. Their successors would have a relatively easy task to show profits, whether they were doing an efficient job or not.

As a second example of the importance of such a technique, let us assume that the contract is cancelled after the sixth month of production. If the termination is not settled on a total contract cost basis, the loss to date of $29,750 will remain on the books and the cancellation will be settled for a reduced figure. A more extreme example of this same point would be if the original order for 2,000 units was reduced to 1,500 shortly after production has begun. If the reduction in the total quantity of the order was accepted on a no-charge basis, the net loss would be about $75,000, as shown in the "Difference" column at the end of the eighth month.

In short, the selling price for any contract on which learning has a material effect, is really a composite of several different selling prices as indicated by the learning curve. This paramount fact cannot be overlooked in the event of cancellation or cut-backs, without incurring substantial losses.

Using the Learning Curve for Control of Direct Labor

Certainly if the reasoning on the subject of learning, followed in the treatment of product costing, is valid, there is a comparable technique which is applicable to the setting and using of labor standards for cost control. First of all, it is clear that random time studies taken of production operations, without correlation to a point in the learning cycle will produce inaccurate results. In the case of an 80 per cent learning curve, a portion of the anticipated improvement is, of course, due to the improved tooling, resequencing of operations, etc. However, probably the largest portion is due to the fact that both operators and supervisors must learn the job. It is not believed that time study can penetrate the inefficiencies of the first hundred units and accurately determine the ultimate standard time which might be reached by the thousandth unit. Hence, it is advisable to take time studies at a uniform point in the production cycle, so that time standards for any group of products are representative of time values after a given number of units of production.

In the case which has been cited to illustrate application of the learning curve to product costing, let us assume that time studies are correlated with production after 500 units and also that the estimate of time required to manufacture the exhaust cones breaks down as follows:

Detailed parts fabrication	30 hours
Final assembly	70 hours
Total	100 hours

It is important to recognize that the above figures are estimates. In the case of detail parts fabrication, the estimate does not correspond to the standard hours. In the case of final assembly, the fact that the estimate corresponds to the standard hours is accidental.

Exhibit 4 shows two separate sets of learning curves reflecting the above breakdown. The detailed parts fabrication was set up on a 90 per cent learning curve and the final assembly was set up on a 78 per cent learning curve. Also, on the unit labor hours line, the total standards as calculated by the estimating department have been indicated in each case at the 500 hour point. This shows the basis for the original estimate and provides the necessary data for accurate reporting of labor efficiency while the contract is in progress.

Assuming lead time of two months for detail fabrication and of one-half month for final assembly, the production schedule to meet the shipping schedule shown earlier is as follows:

PRODUCTION SCHEDULE

Month	Detail fabrication	Final assembly	Units shipped
1	25	—	—
2	75	12	—
3	150	50	25
4	250	113	75
5	250	200	150
6	250	250	250
7	250	250	250
8	250	250	250
9	250	250	250
10	250	250	250
11	—	250	250
12	—	125	250
Totals	2,000	2,000	2,000

With this schedule data and with the curves on Exhibit 4, a projection of the total anticipated hours for each month of production can be calculated. In this calculation, use is made of the unit hours line on the graph. Production for each month has been indicated by small cross lines and the average hours for the month are obtained from the linear mid-point for each month's production.

The method of interpolation should be particularly noted. If the scales were arithmetic, the per unit labor hours could be obtained more readily by calculating the abscissa of the graph as the cumulative production at the beginning of the month plus half the production for the month and then reading the corresponding ordinate. However, since both scales are distorted because they are both logarithmic, the method noted must be used instead. The initial values for both detail fabrication and assembly were read from the cumulative lines

and the subsequent values from the unit line. In checking the graph readings, it should be noted that the accuracy of the graph as reproduced will permit only approximate checks. The anticipated hours can then be tabulated as follows:

EXPECTED LABOR HOURS BY MONTHS DURING PROGRESS OF CONTRACT

	DETAIL FABRICATION		FINAL ASSEMBLY		
Month	Per unit	Total	Per unit	Total	Grand total hours
1	60	1,500			1,500
2	45	3,375	450	5,400	8,775
3	38	5,700	200	10,000	15,700
4	33	8,250	130	14,690	22,940
5	30	7,500	90	18,000	25,500
6	29	7,250	72	18,000	25,250
7	28	7,000	62	15,500	22,500
8	27	6,750	56	14,000	20,750
9	26	6,500	52	13,000	19,500
10	26	6,500	49	12,250	18,750
11			46	11,500	11,500
12			44	5,500	5,500

This, in turn, provided the necessary data for interpretation of daily or weekly labor efficiency reports. The grand total projected hours, as shown on the above tabulation, are compared with total standard hours for each month, or lesser period if desired, to obtain the projected labor efficiency for the period. Total standard hours figures are obtained by multiplying each of the detail fabrication figures shown by 32 and each of the final assembly figures by 70, and adding the results by months. The comparison and the projected efficiency percentages follow:

FORECAST LABOR EFFICIENCY FOR CONTRACT PERIOD

Month	Total Projected hours	Total standard hours	Projected efficiency — %
1	1,500	800	53.3
2	8,775	3,240	36.9
3	15,700	8,300	52.9
4	22,940	15,910	69.4
5	25,500	22,000	86.3
6	25,250	25,500	101.0
7	22,500	25,500	113.3
8	20,750	25,500	122.9
9	19,500	25,500	130.8
10	18,750	25,500	136.0
11	11,500	17,500	152.2
12	5,500	8,750	159.1

If desired, the standards may be adjusted each month according to the projected hours on the learning curve, with the result that labor hours which are in accord with the curve will be reported as 100 per cent efficient. Such an adjustment would be contingent upon the complexity of the standards involved and upon management policies. Whether it is done or not, the data must be available for effective labor reporting.

Better Control and Better Profits

The applications of the learning curve which have been demonstrated here are certainly not the only areas in which the technique by which it is recognized, can be used. As stated earlier, the technique is applicable wherever learning is involved. Attention is called to the nature of this idea and the way in which it makes cost data work for greater profits. If it is an integral part of accounting figures, markedly improved control information will result and, if this information is presented in a systematic way based on prior experience, such figures will exercise a compelling influence on operations.

While it might be argued that there is nothing like showing a loss on the books to incite action from operating personnel, this is a short-sighted answer to the question. Losses shown at the beginning of a job are always shrugged off as "what we expected." High profits later on in the job are a signal for complacency and relaxation of efforts to improve. The learning curve answers both of these situations and provides the continuous incentive which is necessary to maintain a low cost and competitive business.

Applying Statistics to Checking of Vendors' Invoices

by RUTH A. HANNA

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Checking all vendors' invoices may be a costly procedure. Its purpose is to detect errors which would cost the company money. A procedure to determine the optimum compromise between excessive clerical checking costs and excessive losses due to vendors' errors, by the use of statistical methods, is the theme of this paper.

THE VALUE AND IMPORTANCE of statistical controls in office procedures is being recognized more and more. Many magazines are currently publishing articles on the applications of statistics to auditing and other accounting problems. Progressive accountants are becoming aware of the fact that sampling technique is not only economical but often much more sound and efficient than analysis of all items comprising a statistical universe.

The study described in this article was made in a company where a one-hundred per cent checking of accounts payable invoices was becoming a burden due to the increase in volume. Management realized that this increase made the per cent of error potentially greater and that the problem would lend itself quite readily to the more efficient method of sampling.

Distribution by Invoice-Size; Cost of Checking vs. Aggregate Error

The first step was to take a random sample of 3,000 invoices to determine the frequency distribution of the size of the invoices normally being checked (all). From this representative sample, it was estimated that 37 per cent of all invoices were under $50, 47 per cent under $75, and 50 per cent under $100. Three subsequent samples indicated that the distribution varied very little from the original sample. (Exhibit 1)

Since about 50 per cent of all invoices were less than $100, the question which presented itself was, "Is it economical to check invoices under $100, since the size of any error would, for the most part, be relatively small?" To answer this question it was necessary to make a study of the distribution of the errors. This took the form of an analysis to determine the savings or loss to the company as a result of checking invoices completely. A sample of 33,900 invoices

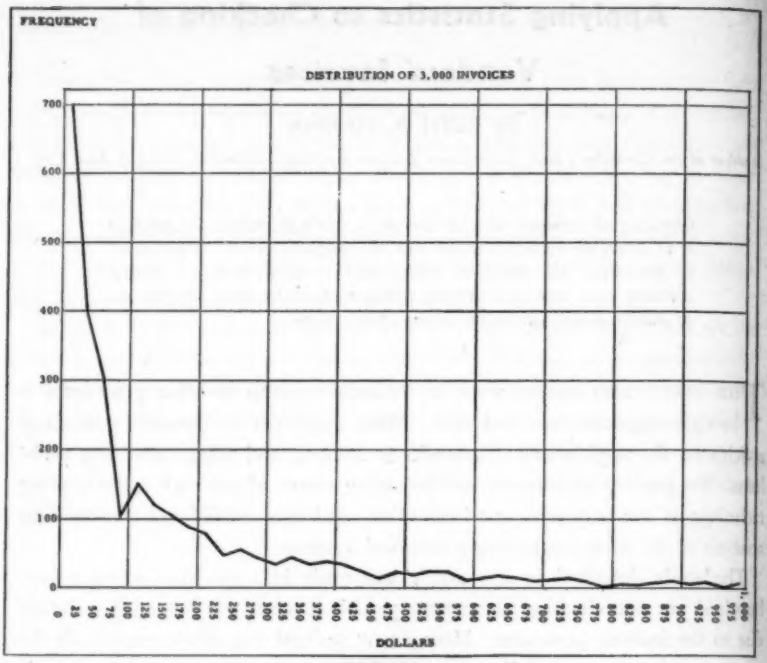

EXHIBIT 1

checked during a given period was taken and the distribution of the 200 errors detected was charted. (Exhibit 2) It was found, by reference to the time and pay of those engaged, that it cost the company more to check all invoices than the loss that would have been incurred had no check been made.

At What Point Does Checking Become Uneconomical?

The next step was to determine statistically the point below which the checking of invoices should be eliminated because it is uneconomical. This was accomplished by calculating the values, based on the sample of 33,900 invoices, for per cent of invoices defective, designated as $\bar{p}$, average error, designated as $\bar{X}$, and total probable error in dollars per year, designated as TPE. These determinations may be followed through in Exhibit 3. To obtain the per cent of invoices defective, the formula was to divide the number of such invoices found by the number checked. Values were then substituted to obtain answers for invoices, respectively, under $50, $75, and $100. To arrive at the average error, the algebraic sum of the errors (errors in favor of vendor positive and errors in

favor of company negative) was divided by the number of invoices with errors for the same invoice size limits. The total probable error figure was next secured in each case by multiplying together the average error, fraction defective, and total number of invoices,—the product being further mutiplied each time by the proportion which the invoices under consideration (under $50, $75, $100 etc.) bore to the total number of invoices.

Exhibit 4 charts the foregoing data and the annual cost of $5,000 for checking all invoices. It shows that $100 was the point below which invoices need not be checked.

Since the cost of checking invoices under $100 was equal to the total probable error in dollars per year, it was recommended that the checking of invoices under $100 be eliminated. This point is the point of economic balance or "break-even" point, since checking either more or fewer invoices would increase net cost.

Periodic Check Against Control Limit of Per Cent Defective

This, then, was the present answer but it needed periodic review. In order to maintain a control over the entire procedure of checking invoices, it was recommended that once every three months invoices be checked completely for a period of a week or until approximately 3,000 invoices had been checked. From this sample of 3,000 invoices two controls would have to be established: (1) A control chart for the per cent found to be defective and (2) a test through which the company would be statistically sure that no loss was incurred by not checking invoices under $100, as a result of a change in the situation.

From the sample of 33,900 invoices it was determined as has been shown in Exhibit 3, that .590 per cent of all invoices were defective. In order to be sure that an appreciable change from this value would be known, it was necessary to establish an upper control limit, which is the limit of error that could be due to sampling. This had to be established each time a test was made, based on the number of invoices checked, using the following formula, which assumes 3 sigma control limits. It will be noted that the symbols, although not the derivation of the formula, are familiar from Exhibit 3.

$$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

where UCL_p = upper control limit of defectiveness
$\bar{p}$ = fraction defective
n = no. of invoices checked
(Source ASTM Manual on Quality Control of Materials)

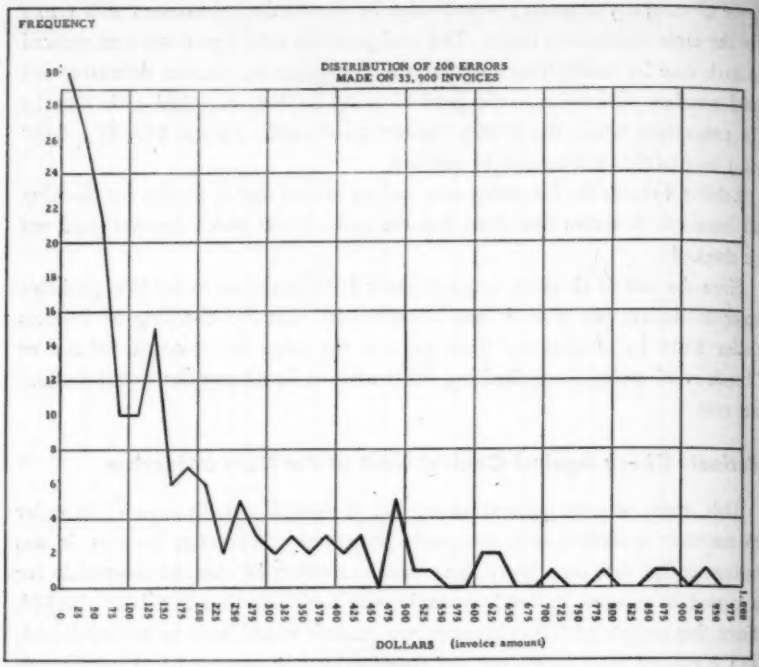

EXHIBIT 2

Hence, if 3,000 invoices were checked during the first test, the upper control limit would be 1.01 per cent. It will be noted that, in working out this formula, the 3,000 invoices is the n value and that the $\bar{p}$ value is taken from the i-d solution in Exhibit 3.

$$UCL_p = .0059 + 3\sqrt{\frac{.0059(1 - .0059)}{3{,}000}}$$

$$= .0101 \text{ or } 1.01\%$$

As an example of the use of the limit so established, if out of 3,000 invoices checked, 24 had errors, the per cent defective ($\bar{p}$) would be 24 divided by 3,000 or .80 per cent. This is .21 per cent below 1.01 per cent, the UCL_p established for 3,000 invoices. It would be safe, therefore, to assume that the pattern of errors of all invoices had not changed for the worse. However, had the per cent defective been greater than 1.01 per cent, it would have been necessary to make an entirely new study, similar to the one already outlined and to establish a procedure based on the new pattern of errors.

Periodic Check Through Standard Deviation of Errors

For those statistically minded, the following procedure was set up based on the Student's "t" test. This involves ascertaining a maximum average error equivalent to the total amount of money that would be spent checking the invoices. It also involves a significance test, to determine whether or not the average error found in the sample could be as great as the maximum allowable average error. If it is very unlikely that the average sampling error could be as great as the maximum allowable average error, it is economically practical to continue not checking. If this is not the case, then it is advisable to check further and possibly start checking completely.

Under the procedure for this, the maximum allowable error ($8.26) was computed by dividing the cost of checking invoices under $100 by the average number of errors for a six months' period. The size of the sample to be taken for this purpose is based on the considerations involved in constructing the table (the express function of which is to assure us of being right 99 per cent of the time.) The steps of the procedure are given in this and the remaining paragraphs under this side heading. The initial two steps are to check all invoices until seven are found with errors and to determine the amount of error made in each of the seven cases, designating an error in favor of the vendor as positive and an error in favor of the company as negative. The average error of the seven invoices is next calculated using the formula for $\overline{X}$ shown in Item 2 of Exhibit 3. It is then possible to use the table to which reference has been made, to determine whether or not the elimination of checking invoices under $100 is economically sound:

AVERAGE ERROR $\overline{X}$	99% CONFIDENCE LIMIT FOR THE AVERAGE	NUMBER OF INVOICES WITH ERRORS
0	$8.26	7
$1.00	7.26	8
2.00	6.26	9
3.00	5.26	12
4.00	4.26	16
5.00	3.26	25

This table is based on a variation of the formula known as Student's t which can be found in K. A. Brownee's book entitled, *Industrial Experimentation*, on page 32,

$$t = \frac{L - \overline{X}}{\sigma/\sqrt{n}}$$

where, in this case, L is the 99 per cent Confidence Limit for the Axerage, $\overline{X}$ is the Average Error, n is the Number of Invoices with Errors and σ is the

DETERMINATION OF PER CENT DEFECTIVE, AVERAGE ERROR AND TOTAL PROBABLE ERROR

1. **Per cent defective (p)**

Formula Used: $\bar{p} = \frac{\text{No. of invoices with errors}}{\text{No. of invoices checked}}$

A. Invoices under $50. (37% of total)

$$\bar{p} = \frac{56}{.37 \times 33,900} = .446\%$$

B. Invoices under $75. (47% of total)

$$\bar{p} = \frac{81}{.47 \times 33,900} = .508\%$$

C. Invoices under $100. (50% of total)

$$\bar{p} = \frac{93}{.50 \times 33,900} = .548\%$$

D. All Invoices

$$\bar{p} = \frac{200}{33,900} = .590\%$$

2. **Average Error ($\bar{X}$).**

Formula Used: $\bar{X} = \frac{\Sigma x}{N}$

where $\bar{X}$ = Average error

Σx = Algebraic sum of the errors
N = No. of invoices with errors

A. Invoices under $50.

$$\bar{X} = \frac{\$170.84}{56} = \$3.051$$

B. Invoices under $75.

$$\bar{X} = \frac{\$395.93}{81} = \$4.888$$

C. Invoices under $100.

$$\bar{X} = \frac{\$565.72}{93} = \$6.083$$

3. **Total Probable Error in Dollars Per Year (TPE).**

Formula Used:

TPE = Avg. error ($\bar{X}$) x Fraction defective ($\bar{p}$) x total no. of invoices/yr. x ratio of total no. of invoices under x dollars to total no. of invoices

There are approximately 150,000 invoices per year.

A. Invoices under $50. (37% of total)

TPE = $3.051 x .00446 x 150,000 x .37 = $755. per year

B. Invoices under $75. (47% of total)

TPE = $4,888 x .00508 x 150,000 x .47 = $1,750. per year

C. Invoices under $100. (50% of total)

TPE = $6.083 x .00548 x 150,000 x .50 = $2,500. per year

EXHIBIT 3

value obtained after each test by using the formula for σ found below. The value of n is dependent upon the value assigned to t from the Student's t Table (column marked 0.01) found on page 181 of Brownlee's book mentioned above. It is found by solving the Student's t formula for n and substituting the proper values for the various algebraic symbols described above. By using the values of t from the 0.01 column of the t table, we are assured of being right 99 per cent of the time.

$$n = \left(\frac{\pm \text{ to } \sigma}{L - \overline{X}}\right)^2$$

It should be noted that the sum of $\overline{X}$ and L at all times must equal $8.26 which is the maximum average error allowable. In other words, if the average error were to exceed $8.26, then the company would be incurring a loss. This amount was based on the annual cost of checking all invoices under $100 and the average number of errors found on invoices under $100 for a 12 month period.

The utilization of this table is a step of general interest. For example, if the average of the seven errors is less than zero, the company is within safe limits and is, therefore, not losing money by the elimination of checking invoices under $100. However, if the average is more than zero, it will be necessary to check further until an eighth invoice under $100 is found with an error. If the average of these eight errors is $1 or less, then the chance of losing money is only one in 100 (remember, we are dealing with invoices $100 or less) or 99 per cent sure. Again, if the average of the errors is greater than $1, the procedure is continued, until the average of the errors is no greater than the designated average for a sample of 9, 12, 16, or 25, as shown above. If the average error is greater than $5, it may not be economical to sample at all, inasmuch as the sample size would have to be so great that it would entail checking invoices very near to 100 per cent.

To carry the test further, it is necessary to calculate the standard deviation of the errors, designated as sigma, for which the symbol is σ, according to the following formula:

$$\sigma = \sqrt{\frac{\Sigma (x^2) - \frac{(\Sigma x)^2}{N}}{N - 1}}$$

(Note: This formula should be used for small samples under 20.)

where

σ = Standard deviation
x^2 = Square of an error
$\Sigma (x^2)$ = Sum of the squares of all errors
Σx = Sum of all errors
$(\Sigma x)^2$ = Square of sum of errors
N = No. of errors

In the application of this formula, in our case, it was found, through adding

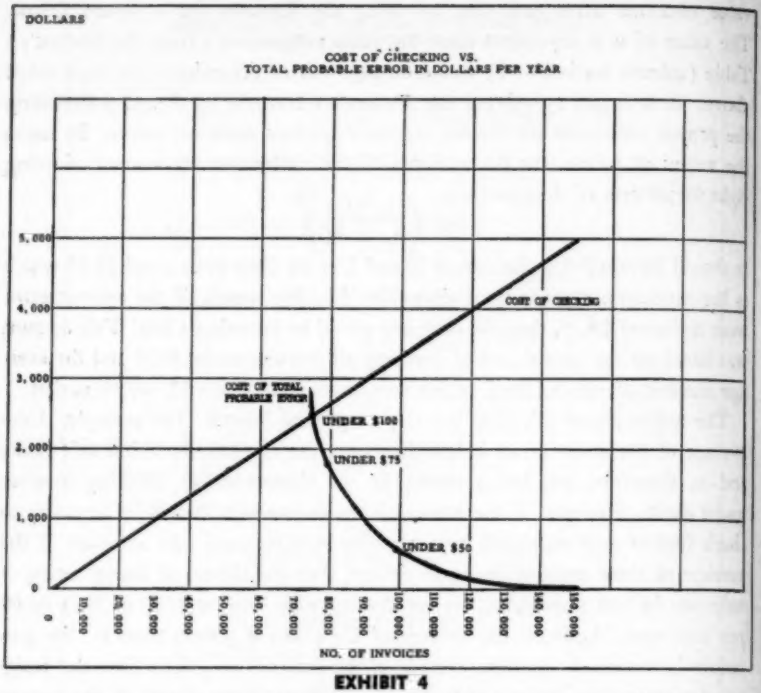

EXHIBIT 4

this standard deviation to the standard deviation of all previous samples, that the standard deviation of errors of all invoices under $100 for the first six months of 1953 was $5.866. A new formula will express such a standard deviation, which results from successive samples of errors, as follows:

$$\sigma_k = \sqrt{\frac{n_1\sigma_1^2 + n_2\sigma_2^2 + n_3\sigma_3^2 \quad \ldots\ldots\ldots\ldots n_k\sigma_k^2}{n_1 + n_2 + n_3 + \ldots\ldots n_k - k + 1}}$$

where

σ_k = Standard deviation of k samples
n = No. of errors in each sample
σ = Standard deviation of each sample
k = No. of samples

(Source ASTM Manual on Quality Control of Materials)

As an application of this, if the standard deviation of the sample of seven errors were $6, and that of all previous samples were $5.866, we would have the following:

$$\sigma_2 = \sqrt{\frac{165 \times 5.866^2 + 7 \times 6.00^2}{165 + 7 - 2 + 1}} = \sqrt{34.66666666} = \$5.888$$

This new standard deviation can then be used to set up a new set of values as set forth in the table already given for the appraisal of the significance of average errors disclosed. These values should be used for the next test three months later. However, when we carried out this procedure as a whole, it was recommended that the standard deviation of successive samples be followed only every six months, if, after a year of testing every three months, the per cent defective did not indicate a marked change in the pattern of errors and if the standard deviation of errors (sigma) did not become too great.

It Is Necessary to Know When the Situation Changes

The two controls set up, the upper control limit of the per cent defective and the standard deviation, can be used effectively to provide warning signals for those conducting the sampling program. For example, if the volume of invoices were to increase, possibly including new vendors, the pattern of errors ($\bar{p}$) might change and the size of the error (σ) might increase considerably. Then it would be necessary to undertake a complete new study, similar to the original one, in order to insure 99 per cent confidence in the program.

The use of this sampling program will permit an increase in volume of work without additional help or a decrease in clerical costs if the volume of invoices remains constant.

It is felt that the sampling technique is here to stay and the successful application to one auditing situation is the prelude to the application of statistical techniques to other auditing and accounting problems.

A NEW TECHNIQUE FOR THE ACCOUNTANT

EVERY NOW AND THEN a new concept in accounting is born. Although unheralded at birth, it is destined for rapid acceptance as accountants test it and find it sound. Examples of such concepts in recent years are the simplification of financial statements, the use of return on capital employed as the measurement of managerial effectiveness, and direct costing. A new concept (in its application to accounting) receiving attention today is that of scientific sampling. Webster's definitions of the two words, "scientific" and "sample," aptly describe this technique: scientific — "agreeing with or conducted strictly according to the principles of exact science;" sample—"a part of anything presented for inspection or shown as evidence of the quality of the whole." More technically, statistical sampling is defined as the study of a selected portion of material or events to determine the characteristics of the universe of which they form a part.

The theory of sampling is not new to statisticians. It was promulgated by Karl Pearson before the turn of the century. In the last decade, this technique has been adopted for quality control of manufactured products, with highly successful results. Auditors, generally accustomed to using sampling methods, are beginning to find that scientific sampling, with its statistical reasoning, results in sounder conclusions with less detailed examinations.

Today, we are on the threshold of an additional application of scientific sampling —that of accuracy control in highly repetitive, large volume, clerical and accounting transactions, such as payroll preparation, vendors' invoice verification and billing. These functions represent a considerable volume of transactions in most businesses and require the services of a relatively large proportion of the clerical personnel.

In these days, when nearly every firm is faced with shrinking margins and increasing competitive pressure, it behooves every accountant to search for cost reductions. What better place for him to start than in the accounting operations? Here lies the opportunity to test the theory of scientific sampling on accounting transactions. For example, instead of complete verification of payroll information, accuracy control could possibly be established by determining a standard of acceptability for each step of the payroll procedure, from reporting of time or production to the preparation of payroll checks. The standard should be scientifically established and should express the percentage and magnitude of errors acceptable in a given number of similar transactions, as for example the application of rates of pay. Samples of each type of transaction could then be drawn from the work of each clerk and verification limited to the initial sample, if within the standard set. Samples showing errors in excess of the standard can then be used for an analysis of the cause of errors and for taking corrective action.

A similar approach might be taken in the verification of vendors' invoices and billings. By so doing, the accountant can expect a saving in verification time, an improvement in the quality of the work, and more rapid indication of the nature and causes of error. Every one of these advantages can be interpreted as indications of potential savings in the cost of clerical work, for which the accountant must be ever alert. The progressive minded accountant should seize every opportunity to exchange information on the results of practical applications of this new technique.

JAMES R. EVANS, *Lancaster*

YOU CAN SAY IT BY FORMULA

WRITERS ON THE SUBJECT of direct costing often find it necessary to resort to rather extensive schedules to explain the differences between the periodic net profit figure derived under the direct cost plan, as compared with the periodic net profit figure reported under orthodox methods of accounting. It is believed that the following analysis sets forth, in a relatively simple way, the principal differences in net profit involved in these comparisons.

Three methods of accounting are considered. They are as follows:

1. *Full standard costs with monthly disposition to profit and loss of variances, including volume variances.* This method is called the "practical" approach for purposes of identification, and it is perhaps the most common method in use.
2. *Full standard costs with monthly disposition to profit and loss of all variances, except for the volume variances, which are carried to one or more reserve accounts.* This method is called the "normal" method in this discussion, because of its association with the idea that normal burden rates bring about variances which will theoretically cancel out in time and that, accordingly, the volume variances should be deferred—at least until year-end, and perhaps longer.
3. *Direct standard costs with monthly disposition of variances and the expensing of fixed factory costs monthly.* This latter point is the principal feature of direct costing from the standpoint of periodic profit reporting.

This discussion will focus attention mainly on the differences in the monthly profit figure appearing in internal reports. The same ideas apply to differences in yearly profit figures, providing no adjustments are made at that time which are inconsistent in any case with the accounting plan used. The symbols used in the illustration are defined as follows:

p = unit price, q = sales in units; so pq = sales revenue
d = standard direct cost; so dq = standard direct cost of sales
r = the part of the standard burden rate representing fixed factory costs
S = period selling expenses; A = period administrative expenses
n = normal production in units for the period—assumed here to be $\frac{1}{12}$ of the anticipated annual volume
m = actual production volume for the period (month)
m = period fixed factory costs under these assumptions

"Normal" versus "Practical"

periodic profit	=	sales	—	cost of sales		—	selling	— administrative
"normal" profit	=	pq		dq — rq		—	S	— A
"practical" profit	=	pq	—	dq — rq	— $r(n-m)$	—	S	— A
Subtracting, the difference	=				$r(n-m)$			

In this case, the profit difference in each period is the amount of the volume variance for that period, i.e., the fixed burden rate times the difference between normal and actual production. This is the familiar difference between these two approaches, inasmuch as the volume variance is typically derived by comparing the fixed burden absorbed by production with fixed burden budget for the period. The practical method reflects unfavorable volume variances as losses and favorable volume variances as profits.

"Practical" versus "Direct Costing"

"direct cost" profit	$= pq - dq$	$- rn$	$- S - A$
"practical" profit	$= pq - dq - rq$	$- r(n-m)$	$- S - A$
Subtracting, the difference	$=$	$rq - rn + r(n-m)$	
Factoring gives	$=$	$r(q-n) + r(n-m)$	
and	$=$	$r(q-n)$	

In this case, the profit difference is equal to the fixed burden rate times the amount by which the sales volume is greater or less than the actual production volume. This is the same as saying that an inventory increase will, under the "practical" method, make for a higher profit than under the "direct cost" method by the amount of fixed factory burden in the inventory increase, and vice versa. If an inventory *increase* persists, you are thus "selling" overhead to inventory.

"Normal" versus "Direct Costing"

"direct cost" profit	$- pq - dq$		$- rn - S - A$
"normal" profit	$- pq - dq - rq$		$- S - A$
Subtracting, the difference	$-$	$rq - rn$	
Factoring gives	$-$	$r(q - n)$	

In this third comparison, the periodic profit difference is equal to the fixed burden rate times the amount by which sales volume exceeds normal production. A simpler way to say this in accounting language is that, if sales volume exceeds normal production, the fixed burden content of the cost of goods sold will be greater than the actual fixed factory costs, thus lowering the profit in comparison with the direct cost plan. Under these conditions, the direct cost plan permits the sales volume to reflect (in higher profit) the greater contribution to fixed charges.

On the other hand, if sales volume is lower than normal production, the direct cost method will show a lower profit than the "normal" method, because the period charge for fixed factory costs will exceed the fixed burden content of the cost of goods sold. In either case, a volume variance may exist under the "normal" method, depending upon the actual volume of production in relation to normal, but this variance is deferred.

For some readers, these illustrations may only further complicate the subject, but it seems to me that they do indicate the profit reporting features of the three principal methods of handling fixed factory burden. Also, in the second illustration above, the most frequently made contrast between direct costing and absorption costing is summarized. Direct costing charges a uniform total of fixed burden against sales, whereas the "practical" approach charges a normal fixed burden rate against every unit sold, plus or minus, as a total, the volume variance for the period. These differences narrow down to a reported profit difference equal to the fixed burden part of the inventory change for the period. For any period over which both sales volume and actual production equal to production volume on which burden rates are based, both methods (in fact, all three methods) will give the same profit result.

JOHN H. KEMPSTER, Boston

Transportation Costs Analysis

by H. G. MILLER

Assistant to the Traffic Manager, Texas Division, The Dow Chemical Company, Freeport, Texas

Where were the cost accountants when the freight rates went up? During the past six years, freight rates have increased almost fifty per cent. This article highlights the need for comprehensive analysis of all components of transportation costs. It is pointed out that if transportation is important in a business, comparison of rates alone will not solve its transportation problems.

ALL TOO FREQUENTLY, neither the traffic managers nor the cost accountants are equipped to furnish management with useful figures on transportation costs. True, the traffic department can usually quote "rates" by truck and rail and occasionally by barge or ship, but freight rates do not tell a complete story. To properly evaluate their problems, the sales department, the purchasing department, and general management need accurate information on the cost of transportation, not just a summary of rates. In bridging the gap between rates and costs many of the techniques of cost accounting can be profitably applied.

Many articles and several books on the accounting aspects of distribution cost have appeared in recent years. Nevertheless, almost without exception they have passed lightly over one of the major elements of distribution costs, the cost of transporting products.

One immediately wonders why a cost factor of major importance has been dealt with lightly in accounting literature. Three reasons which might account for it are:

1. It has been considered the problem of the traffic department.
2. Much transportation cost analysis has been limited to a tabulation of freight rates, which presented little challenge to the accounting profession.
3. The cost has been hidden in a broad accounting category, cost of sales, and the cumulative importance of gradual increases was not recognized.

However, if the analysis is to be placed in its proper perspective, the techniques of cost accounting must be combined with rate analysis for the determination of transportation costs—not just freight rates. We will turn shortly to a simple problem in transportation cost analysis presented to illustrate the difference between costs and rates.

What Has Been the Trend of Transportation Costs?

Before proceeding with the illustrative problem, it may be well to take a look at the trend in freight rates over the past several years. Taking 1947 as the base year equaling 100, the general freight rates applying between Houston,

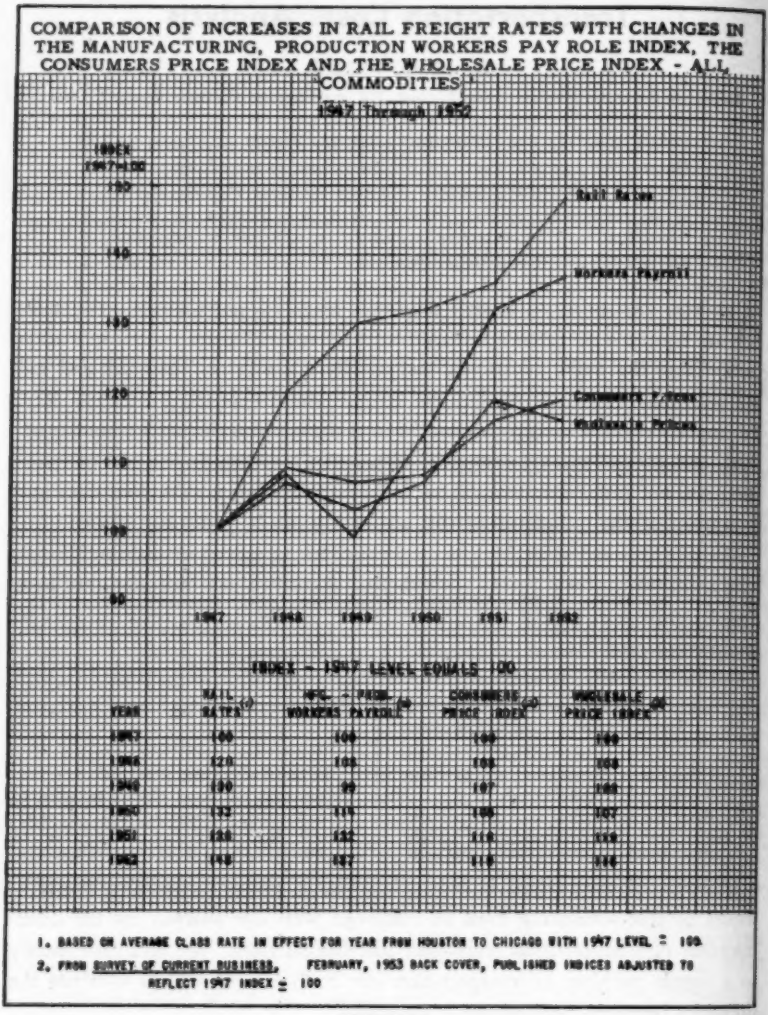
COMPARISON OF INCREASES IN RAIL FREIGHT RATES WITH CHANGES IN THE MANUFACTURING, PRODUCTION WORKERS PAY ROLE INDEX, THE CONSUMERS PRICE INDEX AND THE WHOLESALE PRICE INDEX - ALL COMMODITIES
1947 Through 1952
INDEX (1947=100)
Rail Rates
Workers Payroll
Consumers Prices
Wholesale Prices
1947
1948
1949
1950
1951
1952
INDEX - 1947 LEVEL EQUALS 100
YEAR
RAIL RATES (1)
MFG. - PROD. WORKERS PAYROLL (2)
CONSUMERS PRICE INDEX (2)
WHOLESALE PRICE INDEX (2)
1947 100 100 100 100
1948 120 103 108 108
1949 130 99 107 103
1950 132 111 105 107
1951 138 132 110 119
1952 143 137 110 116
1. BASED ON AVERAGE CLASS RATE IN EFFECT FOR YEAR FROM HOUSTON TO CHICAGO WITH 1947 LEVEL = 100.
2. FROM SURVEY OF CURRENT BUSINESS, FEBRUARY, 1953 BACK COVER, PUBLISHED INDICES ADJUSTED TO REFLECT 1947 INDEX = 100

EXHIBIT 1

Texas and Chicago, Illinois, are plotted for the years 1947 through 1952, in Exhibit 1. The average freight rates for this period are compared with the following indices published by the Department of Labor:

1. Manufacturing production-worker payroll index.
2. Consumers' price index.
3. Wholesale prices—All commodities, Combined Index.

The indices, as portrayed in the exhibit, are adjusted to a base for which the 1947 level of each index equals 100. As indicated in the graph and table, the rail freight rates increased forty-eight per cent between 1947 and 1952, workers' payrolls thirty-seven per cent, consumers' prices nineteen per cent, and wholesale prices sixteen per cent. It is thus illustrated that rail freight rates have increased much faster during the past six years than have costs in many other segments of our economy. It would be difficult to predict the trend for the future since rail rates during the entire period were controlled by the Interstate Commerce Commission. Labor rates were sympathetically controlled during a portion of the period by a different government agency and prices were somewhat more rigidly controlled during part of this period by a third government agency.

Where Were Cost Accountants When Freight Rates Went Up?

All too often the increase in freight rates was passed off with the assumption that nothing could or should be done about it. The increased costs either passed unnoticed into cost of sales or, if noticed, were ignored, since the rate change furnished an acceptable explanation for the increased costs. All too few businessmen took increased rates as a cue to seek the answers to questions like the following:

1. How will the increased freight cost affect profits on the various lines of products? (Analysis might reveal that the increased rates would wipe out profits on certain lines if prices were not increased.)
2. How will the freight rate increases affect the profits in the various geographic market areas? (Profits may be reduced or eliminated in market areas located a long distance from the plant.)
3. How will the increased rates affect terminal operations? (It may render some of the present terminal operations uneconomic and increase the area which should be served by other terminals.)
4. How does the freight rates increase affect the differentials in price on carload, truckload, and shipments? (If price differentials are not periodically re-examined, they may offset only a fraction of the increased cost of handling small lots.)
5. Will the increased freight cost change the picture on raw materials purchased f.o.b. origin? (Often increased rates may make it desirable to pay a higher f.o.b. origin price from a local supplier since the freight differential under the new rate structure may more than offset the price advantage of the distant supplier.)

A simple example will illustrate why the analysis of transportation costs must go further than a superficial analysis of freight rates. Let us assume that a small refinery has to move 100,000 gallons (600,000 pounds) of product per week from the production plant to a terminal located in a large city in a nearby state. The material can be moved by rail in 10,000 gallon tank cars leased by the refinery or by contract truckers who transport products in interstate commerce. The truckers furnish their own equipment. They are limited

by weight restrictions to the transportation of 5,000 gallons per load. The distance from the refinery to the terminal by highway is 90 miles, and 110 miles by rail. By rail the cars must be handled by two railroads and delivered to the terminal by a belt line serving the metropolitan area.

The traffic manager checked the tariffs and found that the following interstate rates apply on the movement:

	RATE PER CWT.	COST PER WEEK
Rail	$0.16	$ 960
Truck	$0.18	1,080

A simple rate analysis indicated that a saving of $120 per week will result from shipment by rail. However, the freight rates do not cover all of the relevant cost factors on this movement.

Considering All Transportation Costs

The following additional cost factors must be analyzed to determine relative cost of the two methods of shipment.

1. Loading cost.
2. Unloading cost.
3. Loss of material.
4. Cost of cleaning and maintaining equipment.
5. Rental cost of equipment.

The techniques of cost accounting can be applied in determining these costs. Since many of them are based on estimated costs for anticipated movements, the cost accountant can perform an added service by furnishing actual cost information to check the accuracy of these estimates. To do this, let us assume that a study of these transportation costs give the results indicated in the following paragraphs.

Loading cost may be considered first. To ship the product by truck, twice as many units must be loaded. Tank cars are spotted at night and can be loaded as convenient during the normal working day. For trucks to operate efficiently, however, the plant must load the units within one-half hour after their arrival. Taking these factors into account, the tank car loading cost is estimated at $5.50 per car or $55 per week. The truck loading cost is estimated at $4 per truck or $80 per week.

Then there is the unloading cost: The trucker plans to use two trucks, each carrying two loads per. However, to do this, he must either load or discharge in the evening. Trucks are not permitted in the plant except between the hours of 8:30 a.m. and 5:30 p.m., Monday through Saturday. The terminal is open 16 hours per day, but operating personnel are not always immediately available. The trucker is willing to pump off his own unit at a flat charge of $1.50 per load to avoid delaying his equipment and to permit discharge in the

evening. Since this is cheaper than the operation could be performed by the terminal, the offer is accepted. The cost of unloading 20 trucks per week is $30. It is estimated it will cost the same to unload a tank car as to load, i.e., $5.50 per car or $55 per week.

Some material will be lost in transit, but how do alternatives compare in this respect? Experience indicates that about ½ of 1% of the material will be lost on transfers by either rail or truck. Since the production cost is $0.06 per gallon this would amount to $30 per week.

The cost of cleaning and maintaining equipment is a factor in comparisons. The 10 tanks cars used in this service must be cleaned once a month for inspection and maintenance. The estimated cost of this operation is $7.50 per car, $75 per month or $17 per week. Tank truckers customarily clean their own equipment periodically, to permit servicing and inspection. No further cleaning will be required.

There is likewise tank car rental cost. The turnaround time on tank cars is estimated as follows:

Loading	1 day
Delivery	2½ days
Unloading	1 day
Return	2½ days
Total	7 days

Based on this turnaround time, 10 cars will be needed in this service. Each car would make 4⅓ trips per month and would travel 953 miles. The 10,000 gallon tank cars can be leased for $85 per month and the railroad reimburses the shipper $0.03 per mile on movements in cars furnished by the shipper. The following is the net rental for tank cars.

Rental—10 cars at $85 per month	$850
Mileage credit	286
Net cost per month	$564
Cost per week	$130

The effects of the cost elements dealt with above may be summarized as follows:

COST OF MOVING 100,000 GALLONS OF PRODUCT FROM PLANT TO TERMINAL

	Cost Per Week	
	Rail	Truck
Freight	$ 960	$1,080
Loading	55	80
Unloading	55	30
Loss Material	30	30
Cleaning	17	0
Net Rental of Equipment	130	—
Total Cost Per Week	$1,247	$1,220

Had the traffic manager stopped with the analysis of freight rates in the above problem he would have moved material by rail and assumed he was saving $6,250 per year. If the above cost figures are correct, it would cost an additional $1,404 per year to move the product by rail.

Cost and Traffic Departments Must Get Together on These Costs

All too often, transportation costs are hidden in the catch-all heading "cost of sales" and receive little attention from the accounting profession. In many industries, transportation costs represent a significant percentage of the sales price, sometimes a greater percentage than the direct labor cost. As already indicated, during the past six years rail freight rates have increased almost 50 per cent and, during the same period labor rates increased 37 per cent, consumer prices 19 per cent and wholesale prices 16 per cent. While there are many factors influencing each of these items which would make it impossible to predict whether or not relative trend will continue in the future, the figures do pose an interesting question. Did the accounting profession and management generally take note of the rapid freight rate increase during this period and adjust sales, pricing and distribution policies accordingly?

Because of the size of the freight bill and its recent rapid rate of increase, it deserves more careful consideration than it has been given in the past. Freight increases should be taken as a cue to re-evaluate prices, distribution methods, and purchasing policies. To analyze freight costs intelligently, however, the traffic manager and cost accountant must combine forces to move from a superficial analysis of freight rates to a meaningful analysis of transportation cost. Only by such a combination of effort can management be furnished with the information which it requires to plan future sales and purchasing policies effectively.

THE WORKSHOP

Inventory Control Through Commodity Standards

by MARSHALL H. OSBURN

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This paper is a case study of the installation of standards for the control and reduction of inventories. Basic concepts are discussed prior to the specific procedures for setting standards. The importance of judgment in the application of standards is emphasized. A procedure for the control of obsolete items is outlined. Numerous forms and reports are illustrated.

THE CONTROL OF INVENTORIES is an important problem today. With a more plentiful supply of materials, businessmen are changing their buying tactics. They are growing cautious, trying to avoid getting "stuck" with excess material. This change in attitude demands the most concerted accounting effort towards the scientific solution of inventory problems.

The objective of this article is to add to well-known approaches a somewhat different one which has been proved highly successful in practice.

Toward Balance Standards from Consumption Standards

One of the best means of effectively and economically controlling any expenditure is through the medium of some form of standard, either historical or predetermined, so that results may be measured and evaluated as favorable or unfavorable. This paper is a case study of an installation of controls which has proved that commodity standards may furnish an effective tool for controlling inventory quantities, particularly with respect to materials. The required detailed analyses can also reveal numerous instances in which substantial savings are attainable through a change in order quantities, permitting more economical quantity discounts. They also direct attention to obsolete or surplus items.

Nevertheless, it must be remembered that facilitating the solution of inventory problems must not be made a means of neglecting them. The development and use of commodity standards and the use of suggested control procedures offer no royal road to the solution of inventory problems. The task involves a volume of detailed considerations which will become evident as the case study unfolds. The plan which will be out-

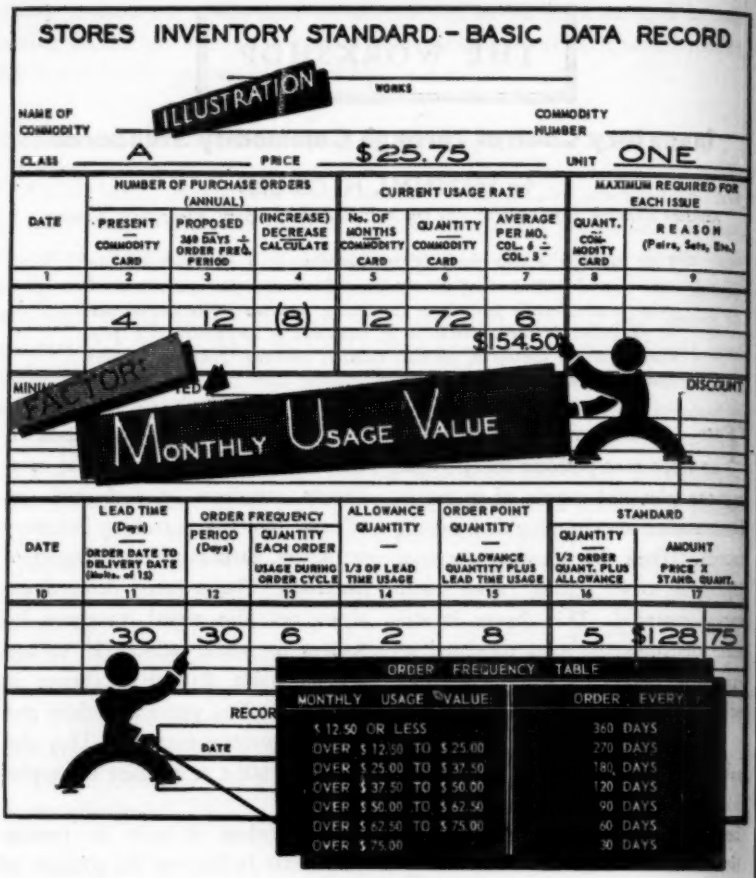

STORES INVENTORY STANDARD – BASIC DATA RECORD
ILLUSTRATION
WORKS
NAME OF COMMODITY
COMMODITY NUMBER
CLASS A
PRICE $25.75
UNIT ONE
DATE
NUMBER OF PURCHASE ORDERS (ANNUAL)
PRESENT — COMMODITY CARD
PROPOSED 360 DAYS ÷ ORDER FREQ. PERIOD
(INCREASE) DECREASE CALCULATE
CURRENT USAGE RATE
No. OF MONTHS COMMODITY CARD
QUANTITY — COMMODITY CARD
AVERAGE PER MO. COL. 6 ÷ COL. 5
MAXIMUM REQUIRED FOR EACH ISSUE
QUANT. — COMMODITY CARD
REASON (Parts, Sets, Etc.)
1 2 3 4 5 6 7 8 9
4 12 (8) 12 72 6
$154.50
FACTOR
MONTHLY USAGE VALUE
DISCOUNT
DATE
LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Units of 10)
ORDER FREQUENCY
PERIOD (Days)
QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE
ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE
ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE
STANDARD
QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE
AMOUNT — PRICE X STAND. QUANT.
10 11 12 13 14 15 16 17
30 30 6 2 8 5 $128 75
RECOR
DATE
ORDER FREQUENCY TABLE
MONTHLY USAGE VALUE
ORDER EVERY
$ 12.50 OR LESS 360 DAYS
OVER $ 12.50 TO $ 25.00 270 DAYS
OVER $ 25.00 TO $ 37.50 180 DAYS
OVER $ 37.50 TO $ 50.00 120 DAYS
OVER $ 50.00 TO $ 62.50 90 DAYS
OVER $ 62.50 TO $ 75.00 60 DAYS
OVER $ 75.00 30 DAYS

EXHIBIT 1

lined, is based on standards which have long been in effect to measure economical consumption of all classes of materials. Each area of operating responsibility is held accountable for above-standard use of materials, through comparison of consumption with dollar standards and results are measured by variances. Although the control of purchases and inventory balances has not been standardized to the same degree as use of materials, we have taken, in order to control monthly inventory balances, initial steps to carry the application of standards to the desired extent and to establish a standard

inventory quantity for each commodity of material.

Using these standards as a basis of measurement, actual inventories will be reported monthly to provide a control for maintaining inventories at an economical level. Financial benefits will materialize from the installation of these controls. A reduction in the amount of money allocated to inventories will be obtained, thus releasing capital for more profitable investment. An out-of-pocket saving will be realized through the reduction of ad valorem taxes levied on inventories.

Four Underlying Concepts — And a Formula for Commodity Standard

Before discussing the detailed procedures, it would be well to point out that several basic concepts must be given careful consideration before inventory standards can be determined accurately. The most important of these factors, as discussed in the following paragraphs, are lead time, current usage, and desired "cushion."

The lead time of a commodity represents the number of elapsed days from origin of order to receipt of material. A representative number of orders is reviewed to arrive at the average "lead" time of each commodity.

As to average actual usage an item may be recorded from perpetual inventory records covering a recent representative period of time. This record will be referred to as a commodity card in subsequent exhibits. The analysis made to determine such average usage will sometimes reveal surplus and obsolete materials which were not discovered through regularly established procedures. Of course, when this happens, immediate steps should be taken to dispose of this material in the most advantageous manner. The method used to disclose and classify such surplus and obsolete material is discussed in a subsequent section of this article.

The third factor, i.e., the allowance quantity or "cushion," is the estimated quantity of an item that should be on hand when material on order is received, so as to minimize the possibility of interrupted operations because of depleted inventories. Experience has indicated that one-third of the current lead time usage, subject to a maximum of ninety days lead time, is a desirable amount to be used as the allowance quantity. To illustrate:

> 120 units are used during a 12 month period so the usage rate is 10 units per month. The lead time is 45 days or 1½ months. 1½ × 10 = 15 units for the lead time period, ⅓ of which is 5 for allowance quantity.

However, the availability of supply, i.e., whether the item can be obtained from a local dealer and whether a substitution can be made in the event the inventory is exhausted merits consideration when establishing this "cushion."

The ordering point is the fourth of the factors named above, which under-

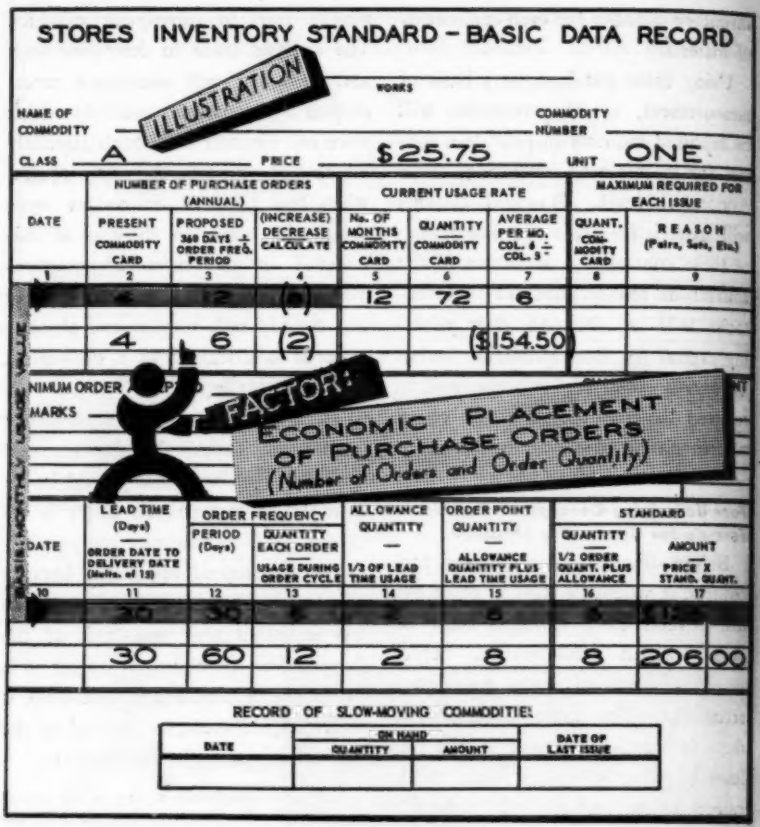

STORES INVENTORY STANDARD – BASIC DATA RECORD
ILLUSTRATION
NAME OF COMMODITY
COMMODITY NUMBER
CLASS A
PRICE $25.75
UNIT ONE
NUMBER OF PURCHASE ORDERS (ANNUAL)
CURRENT USAGE RATE
MAXIMUM REQUIRED FOR EACH ISSUE
DATE
PRESENT — COMMODITY CARD
PROPOSED 360 DAYS ÷ ORDER FREQ. PERIOD
(INCREASE) DECREASE CALCULATE
No. OF MONTHS — COMMODITY CARD
QUANTITY — COMMODITY CARD
AVERAGE PER MO. COL. 6 ÷ COL. 5
QUANT. — COMMODITY CARD
REASON (Pairs, Sets, Etc.)
1 2 3 4 5 6 7 8 9
12 (6) 12 72 6
4 6 (2) ($154.50)
MINIMUM ORDER
REMARKS
FACTOR:
ECONOMIC PLACEMENT OF PURCHASE ORDERS
(Number of Orders and Order Quantity)
BASIS: MONTHLY USAGE VALUE
DATE
LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Mults. of 12)
ORDER FREQUENCY
PERIOD (Days)
QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE
ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE
ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE
STANDARD
QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE
AMOUNT — PRICE X STAND. QUANT.
10 11 12 13 14 15 16 17
30 30 6 2 6 5 (1)
30 60 12 2 8 8 206 00
RECORD OF SLOW-MOVING COMMODITIES
DATE
ON HAND
QUANTITY
AMOUNT
DATE OF LAST ISSUE

EXHIBIT 2

lie standards determination. It represents the quantity normally used during the lead time, plus the allowance quantity. Continuing the illustration used, if "lead" time usage is 15 and allowance quantity is 5, the order point quantity will be 20.

The foregoing factors of lead time, current usage, allowance and ordering point are only partly determining. The standard value of inventory to be maintained for each commodity is calculated by applying the following formulas. One-half of usage during order cycle plus the allowance quantity multiplied by the price of the commodity. (Half is used since it is the average of the maximum and the minimum.) It is obvious that this formula relies on an order cycle usage

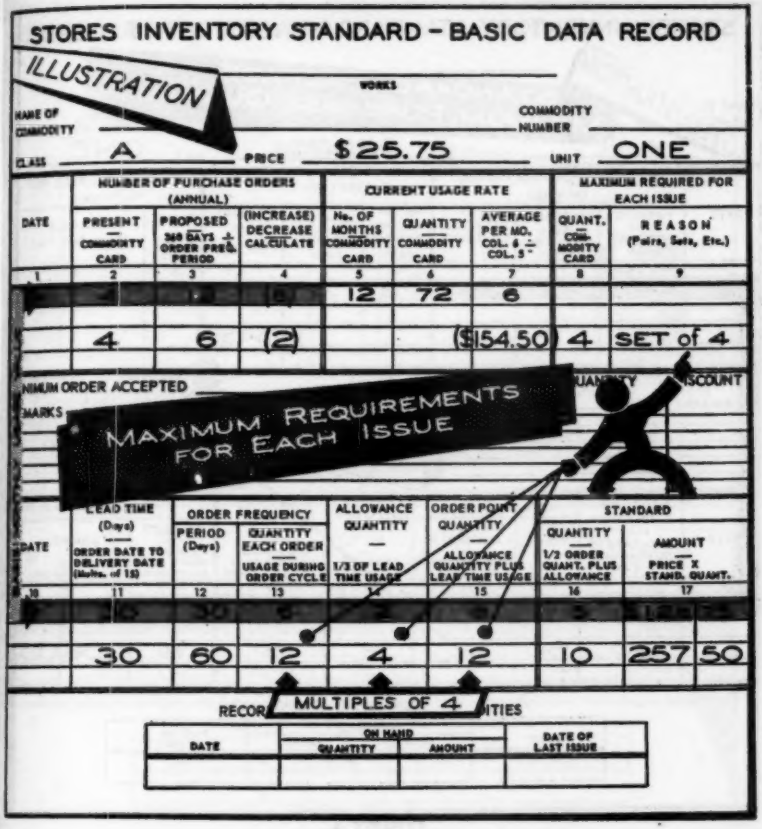

STORES INVENTORY STANDARD – BASIC DATA RECORD
ILLUSTRATION
WORKS
NAME OF COMMODITY
COMMODITY NUMBER
CLASS A
PRICE $25.75
UNIT ONE
NUMBER OF PURCHASE ORDERS (ANNUAL)
CURRENT USAGE RATE
MAXIMUM REQUIRED FOR EACH ISSUE
DATE
PRESENT — COMMODITY CARD
PROPOSED 360 DAYS ÷ ORDER FREQ. PERIOD
(INCREASE) DECREASE CALCULATE
No. OF MONTHS — COMMODITY CARD
QUANTITY — COMMODITY CARD
AVERAGE PER MO. COL. 6 ÷ COL. 5
QUANT. — COMMODITY CARD
REASON (Pairs, Sets, Etc.)
1 2 3 4 5 6 7 8 9
12 72 6
4 6 (2) ($154.50) 4 SET of 4
MAXIMUM REQUIREMENTS FOR EACH ISSUE
MINIMUM ORDER ACCEPTED
REMARKS
DISCOUNT
DATE
LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Subtr. of 15)
ORDER FREQUENCY
PERIOD (Days)
QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE
ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE
ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE
STANDARD
QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE
AMOUNT — PRICE X STAND. QUANT.
11 12 13 14 15 16 17
30 60 12 4 12 10 257 50
MULTIPLES OF 4
RECOR ITIES
DATE
ON HAND QUANTITY
AMOUNT
DATE OF LAST ISSUE

EXHIBIT 3

and that frequency of orders is a fifth factor which must be separately dealt with.

Determining Frequency of Orders

The controlling factor in establishing commodity standards is order frequency. The matter of frequency of placing orders should be carefully considered, as it is easily possible to spend more money through the reduction in inventory. To control effectively the number of orders and still accomplish the objective of a maximum decrease in stores inventories, emphasis should be placed on reducing the number of orders on low-value items and increasing the number on high-value items. In determining how often an order should be placed, the

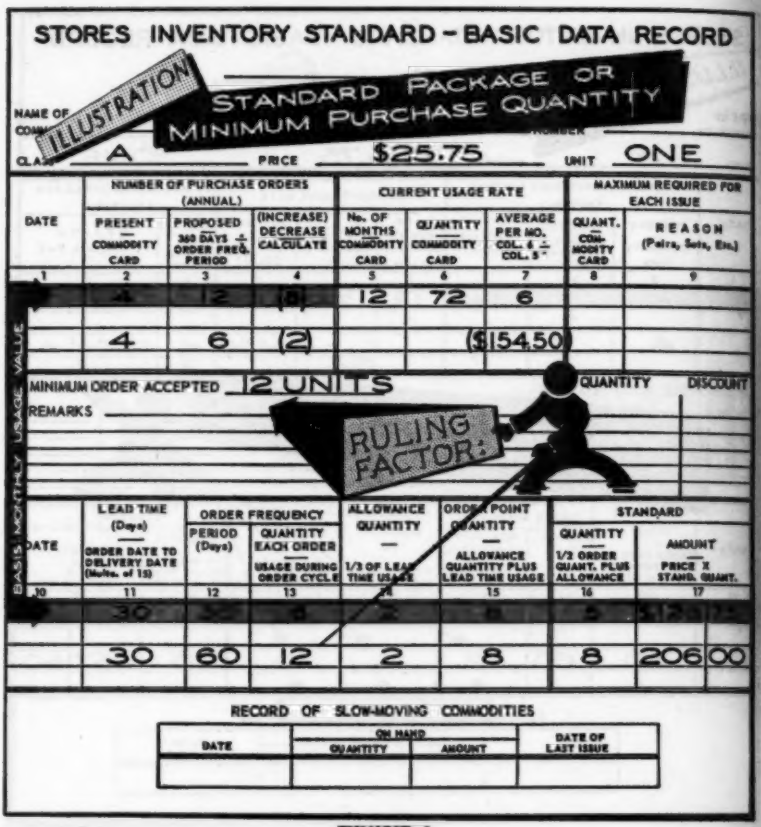

STORES INVENTORY STANDARD – BASIC DATA RECORD
ILLUSTRATION
STANDARD PACKAGE OR MINIMUM PURCHASE QUANTITY
NAME OF COMMODITY
CLASS A
PRICE $25.75
UNIT ONE
DATE
NUMBER OF PURCHASE ORDERS (ANNUAL)
PRESENT — COMMODITY CARD
PROPOSED 360 DAYS ÷ ORDER FREQ. PERIOD
(INCREASE) DECREASE CALCULATE
CURRENT USAGE RATE
No. OF MONTHS COMMODITY CARD
QUANTITY — COMMODITY CARD
AVERAGE PER MO. COL. 6 ÷ COL. 5
MAXIMUM REQUIRED FOR EACH ISSUE
QUANT. — COMMODITY CARD
REASON (Price, Sale, Etc.)
1 2 3 4 5 6 7 8 9
4 12 (8) 12 72 6
4 6 (2) ($154.50)
BASIS MONTHLY USAGE VALUE
MINIMUM ORDER ACCEPTED 12 UNITS
QUANTITY DISCOUNT
REMARKS
RULING FACTOR:
DATE
LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Note, p. 15)
ORDER FREQUENCY
PERIOD (Days)
QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE
ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE
ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE
STANDARD
QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE
AMOUNT — PRICE X STAND. QUANT.
10 11 12 13 14 15 16 17
30 6 2 8 5 12 88
30 60 12 2 8 8 206 00
RECORD OF SLOW-MOVING COMMODITIES
DATE
ON HAND
QUANTITY
AMOUNT
DATE OF LAST ISSUE

EXHIBIT 4

estimated cost of processing the order should be composed with the estimated saving which would result from the expected reduction in inventory value by more frequent ordering. Taxes, handling expense, storage cost and deterioriation must be recognized in arriving at the estimated value of the inventory reduction.

In determining order frequency, it is important that careful consideration be given to the various factors which influence the proper determination of ordering period and quantity.

The primary factors are: monthly usage, economic placement of purchase (frequency and order quantity), maximum requirements for each issue, standard package or minimum purchase quantity and quantity discount.

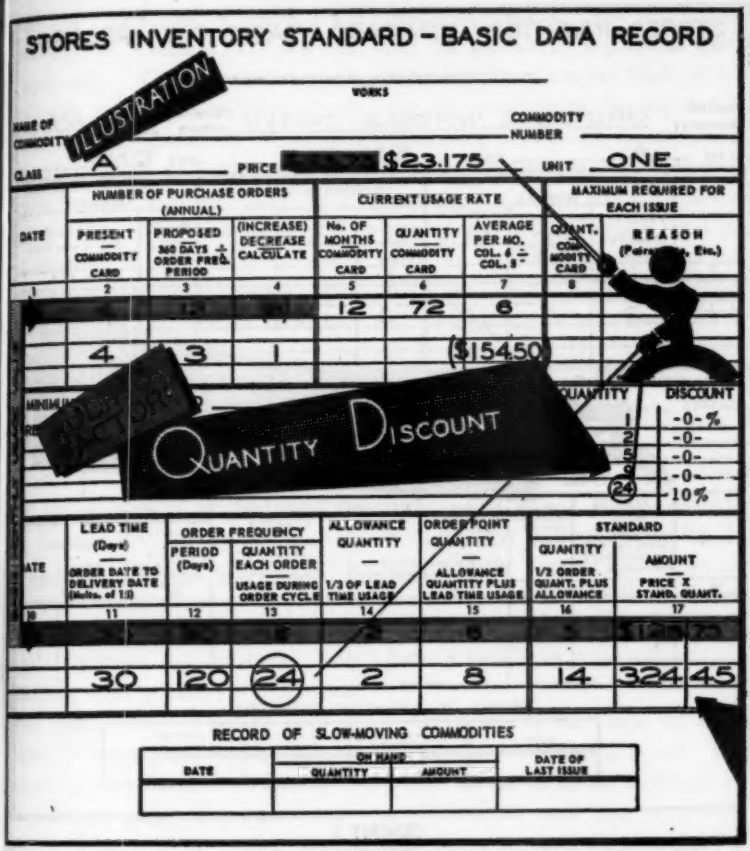

STORES INVENTORY STANDARD – BASIC DATA RECORD
ILLUSTRATION
WORKS
NAME OF COMMODITY
COMMODITY NUMBER
CLASS A
PRICE $23.175
UNIT ONE
NUMBER OF PURCHASE ORDERS (ANNUAL)
CURRENT USAGE RATE
MAXIMUM REQUIRED FOR EACH ISSUE
DATE
PRESENT — COMMODITY CARD
PROPOSED 360 DAYS ÷ ORDER FREQ. PERIOD
(INCREASE) DECREASE CALCULATE
No. OF MONTHS COMMODITY CARD
QUANTITY — COMMODITY CARD
AVERAGE PER MO. COL. 6 ÷ COL. 5
QUANT. COMMODITY CARD
REASON (Fairs, Etc.)
1 2 3 4 5 6 7 8
12 72 6
4 3 1 ($154.50)
QUANTITY DISCOUNT
QUANTITY DISCOUNT
1 -0-%
2 -0-
5 -0-
9 -0-
24 -10%
LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Mths. of 12)
ORDER FREQUENCY PERIOD (Days)
ORDER FREQUENCY QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE
ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE
ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE
STANDARD QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE
STANDARD AMOUNT — PRICE X STAND. QUANT.
10 11 12 13 14 15 16 17
30 120 24 2 8 14 324 45
RECORD OF SLOW-MOVING COMMODITIES
DATE
ON HAND QUANTITY
ON HAND AMOUNT
DATE OF LAST ISSUE

EXHIBIT 5

Monthly Usage Value and Economic Placement of Orders

It is realized that no fixed formula can be universally applied to determine the most favorable ordering period and order quantity. However, for use as a basic guide in the initial development of order frequency, a formula was devised which establishes order frequency in accordance with the value of monthly usage. The order quantity is the usage during the order cycle.

Table for Determining Order Frequency

WHEN MONTHLY USAGE VALUE IS:	TO BE ORDERED EVERY:
$12.50 or Less	360 days
Over $12.50 to $25.00	270 Days
Over $25.00 to $37.50	180 Days
Over $37.50 to $50.00	120 Days
Over $50.00 to $62.50	90 Days
Over $62.50 to $75.00	60 Days
Over $75.00	30 Days

An example of the determination

STORES INVENTORY STANDARD – BASIC DATA RECORD

WORKS

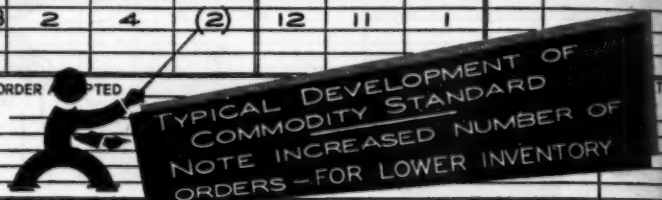
NAME OF COMMODITY: GRINDING WHEELS 24X3X12 — COMMODITY NUMBER: 001-5098

CLASS: A — PRICE: $59.10 — UNIT: ONE

DATE	NUMBER OF PURCHASE ORDERS (ANNUAL)			CURRENT USAGE RATE			MAXIMUM REQUIRED FOR EACH ISSUE	
	PRESENT — COMMODITY CARD	PROPOSED — 360 DAYS ÷ ORDER FREQ. PERIOD	(INCREASE) DECREASE CALCULATE	No. OF MONTHS COMMODITY CARD	QUANTITY — COMMODITY CARD	AVERAGE PER MO. COL. 6 ÷ COL. 5	QUANT. — COMMODITY CARD	REASON (Pairs, Sets, Etc.)
1	2	3	4	5	6	7	8	9
1-1-53	2	4	(2)	12	11	1		

MINIMUM ORDER ACCEPTED

REMARKS



DATE	LEAD TIME (Days) — ORDER DATE TO DELIVERY DATE (Mths. of 31)	ORDER FREQUENCY		ALLOWANCE QUANTITY — 1/3 OF LEAD TIME USAGE	ORDER POINT QUANTITY — ALLOWANCE QUANTITY PLUS LEAD TIME USAGE	STANDARD	
		PERIOD (Days)	QUANTITY EACH ORDER — USAGE DURING ORDER CYCLE			QUANTITY — 1/2 ORDER QUANT. PLUS ALLOWANCE	AMOUNT — PRICE X STAND. QUANT.
10	11	12	13	14	15	16	17
1-1-53	60	90	3	1	3	3	$177 30

RECORD OF SLOW-MOVING COMMODITIES

DATE	ON HAND		DATE OF LAST ISSUE
	QUANTITY	AMOUNT	

EXHIBIT 6

of order frequency through use of the above table is depicted in Exhibit 1. (The first six exhibits to this paper all display this Basic Data Record, which has proven very satisfactory for use in calculating predetermined inventory standards covering each commodity carried in inventory. It will be noted that an effort is made to simplify the computation of the standard by indicating the source of information and method of computation in the heading of each column on the form.)

It will be noted in this case that the average usage quantity for the item exemplified is six per month, with average usage value of $154.50. Reference to the above table indicates that the item should be ordered every thirty days. Since the usage during the thirty day period is six, these fig-

ures (30 "days" and 6 "units") are recorded in Columns 12 and 13, respectively. Columns 14 to 17, inclusive, are simple arithmetical calculations, as previously explained. Columns 16 and 17 show the standard quantity and standard value established for inventory control purposes.

Although widely acceptable, this method is used with caution, since other factors influencing favorable order frequency are not given due consideration. Standards established by the usage value formula are screened by responsible personnel selected for this purpose. The need for such precaution will be disclosed in the next four examples (Exhibits 2-5), each of which emphasizes the influence of a particular factor which may affect sound establishment of order frequency and quantity. Each example also permits a comparison with results obtained on the basis of monthly usage value only, without regard to other factors.

Order frequency has been established, as a matter of policy, not to exceed 12 orders per year, or 1 order per month. In considering order frequency, an additional order will not be placed unless it will reduce inventory $50. or more. This figure is based on the economic value of the difference between the cost of handling an order and the ad valorem tax on additional inventory.

As previously mentioned, emphasis is placed on decreasing the number of orders on low value items and increasing the number on high value items. Exhibit 2 illustrates the result of taking into consideration the objective of controlling or reducing the number of purchase orders placed. Instead of ordering a standard active commodity every thirty days, or twelve times per year, as prescribed by the frequency table, the result of placing such orders on a sixty day basis is developed. This is a reduction of fifty per cent or 6 orders, having the effect of increasing standard inventory value only $77.25, ($206.00 minus $128.75). The criterion of not placing an additional order unless it will reduce inventory $50. or more is bettered in this instance, as the average increase in the example is only $12.88 per order.

Other Influences on Frequency of Orders

There are certain items in stores that are issued and used in sets. This brings in the factor of maximum requirements for each issue to process. Obviously, this must be recognized in developing order quantity, allowance quantity, etc. In this case, as exemplified in Exhibit 3, the usage for each issue is a set of 4. For this reason, the quantity of each order, allowance quantity and order point quantity should be in multiples of 4. The necessity for these multiple quantities is recognized in the illustration, and comparison is made with the standard established through use of the table

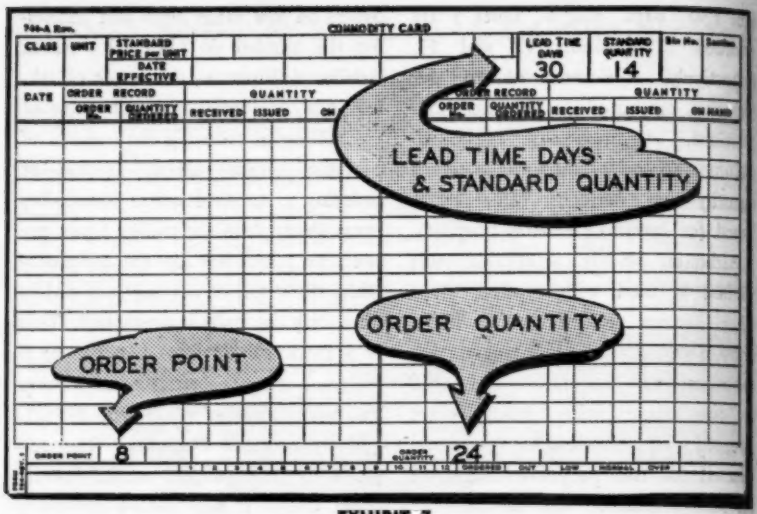


EXHIBIT 7

as outlined under "monthly usage value."

Standard package or minimum purchase quantity is another factor and is exemplified in Exhibit 4. It gives consideration to standard package or minimum purchase quantity. Usage may be at any quantity, whereas purchases are restricted to a minimum of 12 units per order. In this case, the order quantity is established as the minimum quantity obtainable, since there is no choice in the matter. This automatically makes it necessary that order frequency be 60 instead of 30 days.

Quantity discount is also an important consideration in the placing of purchase orders. This is especially true of commodities used in large volume. However, caution should be exercised on purchases of slow moving items that might become obsolete and offset any savings made on the initial purchase. As shown on Exhibit 5, usage is 6 per month, on which there is no discount. By ordering this commodity only 3 times a year instead of 12 there is a difference of 9 in the number of purchase orders placed and a savings of 10% ($2.575 each), or $185.00 per year, with only an average increase in inventory of $195.70.

A Form and a Procedure of Proven Usefulness

Exhibit 6 provides a typical example showing the development of an inventory standard for a grinding wheel. It is interesting for the proposal to increase frequency of orders for lower inventory. Throughout our

MS-A

Comptr. Dept.

STATEMENT OF STORES INVENTORY BALANCES - ACTUAL VS. STANDARD

BOKES _____ MONTH March No. 3

CLASS	INVENTORY DESCRIPTION	STANDARD VALUE AMOUNT	INVENTORY BALANCE 3-31 1953	VARIANCE AMOUNT (1 - 4)	ACTUAL INV. (INCR)/DECR. SINCE 1/1/53	CURRENT MONTH RECEIPTS	CURRENT MONTH ISSUES	NET CHANGE (INCR)/DECR.	REF.
1	2	3	4	5	6	7	8	9	10
A	ABRASIVES	$14800	18350	(3550)	(1629)	2718	3164	446	1
B	BOLTS, NUTS AND SCREWS (Steel & Iron)	2876	3002	(127)	(863)	842	876	36	
C	ELECTRIC WIRE AND CABLE	7826	9643	(1818)	(217)	4325	2189	(2136)	2
D-1	ORD. MAINT. SPARES & REPAIR PARTS	28500	32796	(4296)	1078	3919	4116	197	3
U	TOOLS, HAND & POWER (Inc. Hammer, Brushes, Etc.)								
V	TRACK MATERIALS								
W	WIRE ROPE CHAIN AND ATTACHMENTS								
X	REFRAC. BRICK (Excl. Insuls. Mortar, Pour. & Bldg. Brick)								
Y	CONTAINERS (Returned to Vendor for Credit)								
Z	MISC. STORES - ALL ITEMS NOT OTHERWISE CLASS.	4850	3915	735	735	661	896		
	GRAND TOTAL	169875	190415	(20540)	(740)				

Ref.

Explanation of Changes in Stores Inventory Balances

1. Inventories of certain grinding wheels and abrasives were excessive when predetermined standards were made effective. No purchase orders will be placed for these commodities until actual inventory decreases to the established ordering point.

2. Inventories temporarily over standard because of unusually heavy purchases of wire and cable (approximately $1960) in anticipation of major rewiring program in warehouses.

3. The initial purchase of manganese steel treads was made prior to effective date of inventory standards. These parts were over-ordered due to not having had sufficient experience regarding usage of these treads at time of placing order.

EXHIBIT 8

use of this record, the analysis required to establish accurate inventory standards has revealed several striking examples of uneconomical purchases made because of failure of responsible personnel to take advantage of avail-

EXHIBIT 9

able quantity discounts. For example:

1. It was found that the purchase of four additional grinding wheels per order, or an additional month's supply, would make possible an annual saving due to quantity discount three times greater than the increase in average inventory.

2. Another instance concerned the piecing of an order for three grinding wheels with no quantity discount, whereas if the order had been placed for four wheels the discount would have been 25 per cent. This would have resulted in the acquisition of one wheel at no additional cost.

Supplementary Forms and Reports

It is realized that it will be necessary to revise the inventory standards from time to time for changes in price, lead time or other factors contributing to the determination of the standard. The standard and all basic data relating to it are shown on the commodity card, Exhibit 7. As receipts and issues are recorded on this perpetual inventory record each day, the accountant reviews them and, if necessary, removes the card from the visible posting file for possible revision of the standard.

Results attained under this program are to be determined each month by comparing actual inventory value with the standard established in accordance with the preceding procedures. The control report used in making this comparison is illustrated by Exhibit 8. One feature is that the actual inventory balance at the end of the month is compared with the established standard for each classification. Also, receipts, issues and net change for each classification for the month are shown. Although this report is simple and easy to read, it will not serve as intended unless the accountant analyzes and explains all significant inventory fluctuations. Examples of the type of explanations used for these purposes are indicated on the exhibit.

Certain stores inventory classifications include vital supplies, such as controller parts, switch parts, coils, etc., which are slow-moving or inactive. Some of these inventories may be excessive or may have become obsolete due to discontinuance of equipment for which the parts were originally ordered. Such slow-moving or obsolete commodities should be recorded in the section provided in the lower part of the Basic Data Record. This is conveniently done during the process of posting basic information from the commodity cards for development of standards.

For the purpose of investigation, a questionnaire (Exhibit 9) is prepared in duplicate by the storekeeper and the original forwarded to the supervisor of the department where the slow-moving material is used. Commodities reflecting no issue within the past twelve months are listed on the questionnaire from information on the basic data record. Columns 1, 2, 3 and 4 of the questionnaire showing commodity number, quantity description, and date of last issue, are filled in from perpetual inventory records and Columns 5, 6, 7 and 8 showing recommended maximum and minimum stock, surplus, and recommended disposition of surplus quantity, are filled in by the department supervisor. Upon return of the questionnaire, the storehouse file copy is

destroyed and standards are established in accordance with regular established formulas. A record is maintained, for explanation purposes, of the quantity currently on hand above standard. Substantial reduction in inventories should be accomplished through the use of this questionnaire.

Surplus and obsolete stores material thus revealed (Column 7) will be reported to the department or employees assigned the responsibility of disposing of it. Every effort should be made to effect disposition in the manner most advantageous to the company. Some outlets are used at another location within the company, return to manufacturer, and sale to outside source such as employees, similar industrial concerns and second-hand dealers. Scrapping of the material should not be authorized until every known source for disposal has been completely exhausted.

Reasonably Expected Benefits

Although we are in the early stage of developing this inventory control program, the results thus far have been most gratifying. It appears that an inventory reduction of at least thirty per cent is possible. In addition to releasing a large sum of money for other uses, a sizeable saving will be effected through decreased ad valorem taxes, elimination of storage and handling costs and the reduction of losses through deterioration and obsolescence of materials. Also, we will be in a much better inventory position in the event of a reversal of the upward price trends experienced during recent years.

Inventory Control Through Budgeted Turnover

by CHARLES H. GLEASON

Management Consultant, Warren, Pennsylvania

In the absence of other variables, reduction in inventory increases net profit. A system of inventory control based on standard turnover rates is outlined in this article, together with the reports needed to implement the system. Segregation and analysis of surplus inventory items is an important feature.

INVENTORY IS INVESTED CAPITAL. Many companies expect a twenty per cent to twenty-five per cent annual return on their investment before income taxes. The more capital invested in inventory, per dollar of sales, the greater the burden on management to reach this goal. Increasing turnover reduces required investment for the same annual sales volume. It is principally through control of turnover that the procedure to be described in this article effects inventory control.

However, since management must maintain its operating facilities as a going business, this sometimes requires the manufacture of inventory beyond requirements of the immediate sales picture but in accord with the slightly longer term sales picture. Or it may require a reduction in the operating rate of the plant for the same reasons. Hence, success in inventory control can be attained only where management has a sound inventory policy and adheres to it. Inventory control is not something that can be turned on and off like a water faucet, and still operate effectively.

From the standpoint of inventory control, there are two major classifications into which manufacturing companies can be divided: companies which manufacture a standard line of items and stock and catalog them, and companies which manufacture only to specific orders from customers. Some companies fall into both classifications. Control is basically the same for each group, except that the job-order manufacturer is not concerned with finished inventories for which he does not have an immediate customer. Also, a major part of his raw materials and purchased components is acquired for specific customer orders. Here, his concern is that he does not purchase more material than is actually needed. Common stock items of raw materials and supplies present the same inventory control problem for the job-order manufacturer as for the manufacturer building to stock.

BUDGETED AND ACTUAL RELATIONSHIP OF INVENTORY TO SALES OR PRODUCTION

September 1953

	FINISHED & IN-PROCESS		RAW MATERIAL	
	1952	9 Mo. 1952	1952	9 Mo. 1953
Sales—Gross–(T.M.C.)	$5,350,000	$4,650,000		
Sales Value Production–(T.M.C.)			$5,500,000	$4,560,000
Materials Consumer			2,100,000	1,680,000
% Materials consumed to Sales Value Production (T.M.C.)			38.20	36.80
Average Inventory—Period				
Finished	327,300	364,500		
In-Process	100,700	110,500		
Raw Materials			480,000	485,000
Total	428,000	475,000		
Months Inventory	.960	.920	2.74	2.60
Actual Inventory—End of Period				
Finished	365,600	456,500		
In-Process	114,400	113,500		
Raw Materials			507,000	580,000
Total	480,000	570,000		
Months Inventory	1.075	1.100	2.90	3.10
Projected 12 Months 1953				
Sales—Gross (Budget) (T.M.C.)		5,700,000		
Sales Value Production (T.M.C.)				5,605,000
Materials Consumed				2,060,000
Inventory		475,000		430,000
Months Inventory		1.000		2.50

Note: Due to actual sales for period exceeding budget average, the flexible budget control allows a higher dollar inventory, at budget turnover, than the 12 months projection inventory.

(T.M.C.) Total Manufacturing cost.

All sales and inventory figures are hypothetical.

EXHIBIT 1

Inventory Carrying Costs

There are many reasons for controlling inventory. Generally, they are comprehended in the thought that inventory is not, in itself, desirable. It is, however, necessary. Also, inventory control has as an objective the controlling of the carrying costs associated with it. Costs of carrying inventory vary with industries. For

perfectly good reasons, there may be considerable differences even among companies in the same industry. Studies that have been made show that annual carrying costs vary from twelve per cent to thirty-five per cent of inventory values. The thirty-five per cent probably applies to exceptional operations. The general average is probably around fifteen per cent.

Inventory carrying costs represent:

1. Warehouse occupancy cost: heat, light, building maintenance, taxes, building insurance.
2. Warehouse labor, including labor extras for social security, unemployment insurance, compensation insurance, vacations, pensions, etc.
3. Operating and maintenance costs for warehouse handling equipment.
4. Insurance on stocks and handling equipment.
5. Interest on money invested in inventory, warehouse building, and handling equipment.
6. Obsolescence and damaged stock write-offs.

Starting Point for Control

To control inventory, and the carrying costs, there must be (1) a clear desire for it by top management and a definite appreciation of its value to the organization, (2) a control plan that is realistic and based on attainable goals and, (3) delegation of responsibility to someone with both the authority and the ability to install and operate an effective control system. The tools required are:

1. Sales forecasting—to determine the probable volume and make-up of sales and the probable seasonal variations.
2. Production planning—to schedule production for best utilization of production equipment and labor, with a minimum of overtime premium costs and still have the right finished goods inventory available when the customer wants it, with satisfactory turnover of inventory investment.
3. Purchasing—to obtain the necessary materials, components and supplies, when needed in the proper quantities and at a satisfactory price.
4. Production control—to schedule and load the machines and departments, and control the flow of work through the plant so that production planning goals are met.
5. Cost accounting—to provide the accounting records on raw materials and purchased components, the value of issues from stock to production departments, the changing value of in-process inventory and the quantity and value of finished goods placed in the warehouse.

In respect to these costs and using these approaches to the problem, the likely savings are much larger than most managements realize. To express it in turnover, in line with the thinking on which this article is based, a company with $10,000,000 cost of sales, making two turns a year, with a fifteen per cent carrying cost of inventory, has an expense of $750,000. By accelerating turnover to four times, carrying costs are reduced to $375,000, a fifty per cent cut, making an annual improvement of $375,000 in company profits. Stating it from an investment viewpoint, a company with $10,000,000 cost of sales, making two turns a year, can reduce its investment $2,500,000 by accelerating turnover to four times. This means $2,500,000 is released for more profitable employment. Such savings are worthwhile.

SURPLUS ITEMS REPORT

September 1953

RAW MATERIALS:	
Material #35	$30,000
Due to tight market, we built up stocks. This represents three months' excess over normal requirements.	
Material #88	25,500
Inactive stock due to specification change requiring immediate change in material. Will try to dispose of this stock.	
Material #103	20,500
Accumulation of new program material. When program is actively producing, this will be considered active inventory.	
TOTAL—Raw Materials Surplus Stock	$76,000
FINISHED GOODS:	
Stock #22	$25,000
Seasonal increase in production in order to level department operating hours and provide for Fall Peak demand.	
TOTAL—Finished Goods Surplus Stock	$25,000

EXHIBIT 2

Inasmuch as this is a case study, it is appropriate, for clarity, to indicate the nature of the background operations before going on to the application of inventory control here presented. This control plan covers an installation in several plants, which make small metal stampings, fine wire, wire parts, plastic moldings and assemblies of these items. In addition, there are shops for making molds, dies, and tools, and a shop which designs and builds production equipment. Annual production runs to millions of items.

The inventory control plan is based upon setting an overall plant turnover for raw materials based on usage and a turnover on in-process and finished stocks based on total manufacturing cost of sales. Since the cycle of production from raw to finished saleable products is short, no separate control is kept on in-process inventory, it being included with finished stock. In-process inventory is controlled by control of raw materials and finished goods, coupled with good production control to keep in-process goods moving through the plants.

Determining Standard Turnover

Optimum turnover of raw materials inventory is determined through analysis of each group or kind of materials and parts purchased or manufactured, using the "maximum-minimum ordering-point" technique, which is one of the best ways of de-

termining optimum inventory and is applicable to both large and small companies. Under this procedure, four benchmarks are established:

1. Maximum inventory of the item, determined by the re-ordering point and standard ordering quantity.
2. Minimum inventory. This is the "cushion" stock or margin of safety below which stocks are not to go except in case of emergency or temporary abnormal usage requirements.
3. Re-ordering point. The sum of the minimum inventory and the projected quantity of stock required for use during the interval between placing the purchase order and delivery.
4. Standard ordering quantity. The quantity to be purchased or manufactured at any one time. It constitutes the most economical quantity to buy or manufacture. Special factors to be considered are obsolescence, a very important item with many companies, possibility of physical deterioration while in storage and purchasing, accounting, and disbursing costs. The same technique can be used in determining finished goods quantity.

The turnover goals, or budgets, were established originally from analysis of historical data on inventory, consumption, and sales, tempered by knowledge of special circumstances affecting particular situations and published statistical data. Constant analysis is made of stocks and turnover attainment. This continuing program of analysis is assurance that optimum turnover budgets will be used for each plant.

Control Reports Which Go With the System

After month-end closing and receipt from each plant cost accountant of the monthly manufacturing cost report showing sales value of production and materials consumed, the general accounting department issues Exhibit 1—"Budgeted and Actual Relationship of Inventory to Sales or Production." This goes to the plant managers, production control supervisors, cost accountants and general manager and the controller.

Finished and in-process stocks are dealt with in the first pair of columns. As stated, these are controlled through budgeted turnover based on total manufacturing cost of gross sales. To this end "Projected 12 months 1953" at the bottom of Exhibit 1, shows the annual budgeted total manufacturing cost of sales and what the year-end budget should be at the budget turnover rate. This budget turnover rate is the control turnover figure against which the average and month-end actual turnovers are judged. If there is a revision made during the year of the 12 months projection, such revision will automatically change the projected year-end budget, since the dollars of inventory allowed is a flexible total. *The turnover rate is the fixed factor of control,* and the allowable inventory of finished and in-process stocks at any time during the year depends on actual total manufacturing cost of gross sales.

The sales and production data at the top of the exhibit represents the base to which the turnover rate is applied to determine allowable inventory. "Average inventory—period"

DIVISION SUMMARY—INVENTORY ANALYSIS REPORT

September 1953

RAW MATERIALS

Product Plant	Total Inventory	Surplus Items	Net Inventory	MONTHS STOCK Actual	MONTHS STOCK Budget	Allowable Stock	Inventory Excess
A	$ 580,000	$ 76,000	$ 504,000	2.70	2.50	$ 466,000	$38,000
B	670,500	55,500	615,000	3.45	3.40	606,000	9,000
C	178,700	—	178,700	2.20	2.55	207,000	(28,300)
D	619,000	20,000	599,000	2.35	2.30	585,000	14,000
Total	$2,048,200	$151,500	$1,896,700			$1,864,000	$32,700
August	$2,062,600	$158,000	$1,904,600			$1,843,000	$61,600
July	2,048,100	165,000	1,883,100			1,795,400	87,700
June	2,020,200	140,000	1,880,200			1,850,500	29,700

FINISHED & IN-PROCESS

A	$ 570,000	$ 25,000	$ 545,000	1.06	1.00	$ 517,000	$28,000
B	577,000	—	577,000	1.62	1.50	535,000	42,000
C	380,000	—	380,000	3.05	3.00	373,000	7,000
D	1,090,000	75,000	1,015,000	2.60	2.75	1,075,000	(60,000)
Total	$2,617,000	$100,000	$2,517,000			$2,500,000	$17,000
August	$2,640,500	$110,000	$2,530,500			$2,495,000	$35,500
July	2,563,000	118,000	2,445,000			2,420,000	25,000
June	2,544,000	109,000	2,435,000			2,390,000	45,000

Note: 1. Total inventory figures are before any deductions for balance-sheet reserves.
2. Excess inventory represents amount the net inventory is over the budget stocks for going rate of sales and production.

EXHIBIT 3

shows the trend, which is a leveling factor over the months, "Actual inventory—end of period" shows the month-end results. Both average and actual inventory positions are necessary for proper analysis. It is significant to notice that inventory figures reported are before any reserves which may have been set up to take care of obsolescence, etc. Until such time as the stocks are charged off and disposed of, or are written down on the inventory records, they are reported at original book value.

As with finished and in-process stocks, raw materials—the subject of the second pair of columns of Exhibit 1—are controlled through budget turnover. However, usage is now the base, instead of gross sales cost. Any change in the ratio of materials consumed to total manufacturing cost of

sales value of production, automatically changes the allowable inventory under this flexible control procedure.

Under "Projected 12 months 1953" —the "sales value production, total manufacturing cost," is gross sales plus projected year-end finished inventory, less actual finished inventory at the beginning of the year. "Materials consumed" is a percentage of the total manufacturing cost of sales value of production, as determined by the plants' actual materials consumed during the reporting period, as shown at the top of the statement. The "inventory" amount is determined by the budget turnover or number of months of allowed stock.

An important factor of this control technique, with respect to all classes of stocks, is that it is continually responsive to changes in sales and the production level of the plant. A major expansion in plant capacity and sales immediately results in increased dollars of inventory allowance. Operating men have no trouble understanding this kind of control after it is explained to them.

Surplus Items

One of the troubles in many inventory-control plans is that they do not recognize reality and admit that there may be items in the inventory which must be made exceptions of if a fair, honest task is to be set for operating and production control personnel. The plan recognizes this. The plants are not only relieved, but these special items are highlighted every month until they are eliminated. This is done through the simple procedure of the Surplus Items Report, Exhibit 2.

This shows the surplus items carried in the September inventory on Exhibit 1. Each month, this report is reviewed and changed as changes occur in the items. Before any item can be added to the report, a full explanation must be made to the controller, who is responsible for the decision on whether an item shall be listed. There will be no disagreements on this point when operating men once accept the control plan as fair and workable and they know that, once an item is on the surplus report, it remains there until action has been taken.

Summary Analysis by Plants

As soon as all the individual plant reports are issued, a Summary Inventory Analysis Report, Exhibit 3, is prepared, to show the consolidated totals for all plants. Each of the plant managers, production control, and cost men receives a copy of the "Summary," together with the particular surplus items report for his plant.

On the summary report, the plant is allowed credit for surplus items in comparing performance with budget allowable stock. The "allowable stock" is computed on "net inventory" after deducting surplus items, so that any excess inventory is definitely

chargeable against the plant's performance. All alibis are eliminated through this adjustment for surplus or special items.

Review With Supervisors — Revising the Standards

An important part of this inventory control program is the review meetings. These are called by the controller, each plant group by itself, and are attended by the plant supervisors of production control, cost accounting, purchasing and production planning. Sometimes the plant managers or other operating supervisors sit in. It is well to have the managers participate, since their attendance indicates that they understand the program and are giving it the weight of their support.

In the formative stages of getting the program underway, meetings are required every month. After the program is moving along satisfactorily, meetings can be held every other month. We believe that no longer than the sixty-day interval should pass without a meeting if the program is to continue to be effective and command the attention it deserves.

At these inventory meetings, discussion should cover all matters affecting inventory size and control, purchasing problems and the ordering cycle, progress on steps being taken to correct particular situations which are not satisfactory, surplus items and their elimination, the effect of other plants' operations on the inventory, etc. These round-table discussions create a spirit of teamwork between plant and staff personnel, lead to solution of problems, and provide the spark needed to make the program successful.

As the control program progresses, it will develop that many of the original budget standards of allowable months stock or turnover could be tightened, resulting in a higher turnover. In a few cases it may be necessary to reduce the turnover on finished goods to improve service to customers. This is a continuing process of working toward the objective of the optimum turnover for maximum return on investment consistent with the overall policy of any progressive, growing company.

Through the inventory control plan and meetings, both the operating personnel of the plants and the staff men obtain a better understanding of the economics of inventory in relation to sales and return of investment.

THE COST FORUM

MANAGEMENT'S RESPONSIBILITY FOR EMBEZZLEMENT PREVENTION

Editor, N.A.C.A. Bulletin:

IT IS MY FIRM CONVICTION, based on firsthand experience in at least five cases involving large sums of money and numerous minor cases, that the primary responsibility for the occurrence of embezzlement lies with management. I believe that the management must provide a good system of accounting with adequate internal control and that it should employ a firm of independent public accountants to regularly audit the records, without placing undue restrictions upon their work. Also, if the company is large enough, a staff of internal auditors might well be employed to make periodic tests of the system of internal control and particularly to watch for danger signals pointing toward embezzlement.

But all of this is not enough. Too often when an embezzlement is uncovered, the management seeks shelter in having worked toward these specific protections, instead of asking "What have we done or failed to do that caused the individual to do this?"

First of all, I believe that management should be alert for the danger signals related to embezzlement which were outlined so well by Mr. Roy C. Taylor in his article published last February in the *N.A.C.A. Bulletin*. The management, whether it be the general manager of a small establishment or any person in a managerial position in a large organization, should keep as close as possible to each individual in a key position, by observing his actions, inquiring of the well being of his family, assisting him through a financial difficulty whenever possible, encouraging him to do a better job, and, especially, acquainting him with the future that lies ahead for him as a responsible employee in a position of trust. Management personnel should do a real job of "selling" a promising man on the future and appealing to his pride. By such methods, much can be done toward developing a valuable employee. Is this not an easier and a more pleasant job for management than spending its time and energy detecting misappropriations?

Secondly, I believe that management could develop a training program for each man who shows signs of progress. Such a program could help him to improve himself by pointing the way toward a brighter future by training for a more responsible position. With a little encouragement, most employees would be eager to devote their spare time to building for the future. No one can stand still at one point very long. If he is not moving forward, at least in his thinking, then he certainly is losing ground. Usually when an employee gets the feeling that he is not moving forward, that is the time when he might be tempted.

In short, management cannot afford to depend on the auditors alone for protection. Nor can it expect the employment personnel to eliminate those who might conceivably be tempted. It is not possible to determine by an interview or tests at the time of employment that a person may some day be tempted. Ordinarily the person who commits such misdeeds is one who has a clean record and has a number of years of service with the company. Is it not a persuasive consideration that the opportunity would never exist if a person had not reached a position of trust through ability and favorable traits of character?

Thus, in most cases, back of the fraudu-

lent acts is a set of circumstances or a state of mind and not a recognizable trait of character that causes a person to veer from the "straight and narrow" path. The circumstances existing at the time of the misdeeds may not have been present at the time of employment. In other words, often, the embezzler is not born but is developed over a period of years—a result which may be caused by either internal or external happenings.

Seldom does it turn out that the person accepted the position with the deliberate aim of defrauding his employer. Instead, it is usually an apparently honest person who starts by misappropriating small amounts, with every inward intention of replacing at an early date the funds so "temporarily borrowed." But, gradually, the aggregate amount becomes so large that he realizes that he will never be able to repay the amount. It is then that he goes on with reckless abandon, using every possible means at his disposal until finally he is "caught" or his conscience causes him to confess.

The problem of minimizing embezzlements is one which must be dealt with daily. No business is too large or too small for the management to take the leading role in the prevention and detection of embezzlement. The management has or should have daily contact with those employees in a position of trust. By regularly observing such employees, inquiring about their work and studying reports, the management is in the best position to look for the danger signals and direct abilities to normal outlets.

While it does frequently happen that weaknesses are discovered during an audit, the primary protective measure against embezzlement is that of employing preventive efforts toward minimizing irregularities, through closer daily contacts with persons in key positions. This can best be done by management.

VERNON G. SHEFFIELD, *Houston Chapter*

WHAT IS A UNIT OF EQUIPMENT?

Editor, N.A.C.A. Bulletin:

UNIT OF EQUIPMENT has a different meaning from company to company. Even within the same company, the interpretation of the word varies with the point of view. A department with all its component assets might be described as a productive unit. Another point of view is that a building embracing related cost centers is a manufacturing unit. But, to the property accountant, the machine is defined as a unit. Decisions on maintenance and repairs hinge on this definition. What would be a repair to a department as a unit would be a capital addition to a machine as a unit.

To cite a fictitious example—An oven costing $1,000 is installed in a department as a replacement; the total investment in the department is $50,000 and the total building investment is $500,000. If the point of view dictates that the unit is the department or building, a replacement of the oven seems to be nothing but a repair of the existing unit as it adds no appreciable life or value to the above building or department but only keeps it in operating order. Consequently this expenditure is a legitimate repair charge. On the other hand, if the machine is considered a unit, the transaction is a replacement and the old oven should be written off and the new one capitalized. As another example, if a motor is a unit and is replaced, there is no question that the replacement is a capital charge and the old motor is retired. But, if a machine including a motor is a unit, a replacement of the motor becomes a repair to the machine.

With the definition of a unit paramount, why not describe a unit as "an operable piece of equipment." As a representative example, a centrifugal must have the following parts to be classed as a centrifugal: bowl, shaft, case, base, and motor, with or without starting box. It must have these

to be operable in a practical sense. In addition to this, there might be accessories as a hydraulic controller, brake, etc. To the cost of the centrifugal, including the above named items, must be added the installation cost which makes the item ready for plant use.

The main controversial item among those just named would probably be the motor. It might possibly be considered as a unit, but is it of any value whatever unless it is performing some duty. If some part is attached to the shaft of the motor, such as blades, it becomes a fan, which is a unit. The fan unit includes motor, blades, switch and housing (guard). Extending the shaft of a motor might make the motor into a line shaft. The line shaft now becomes the unit, which includes a motor, a shaft, pullies and supports. The motor should not be capitalized as a unit. It should be included as an integral part of a capital item. Spare motors, just as spare valves and fan blades, should be charged to mechanical stores inventory as spare parts.

Assume that the contrifugal mentioned above was purchased for a particular job. As long as only this job is accomplished, it is immaterial if it is powered by one motor or another, the cost difference from year to year not being the problem of this article. If a larger motor must replace a smaller one, the value of the centrifugal should remain the same, as its function has not changed. The cost of the replacement motor should be charged as a repair to the department and credited to the mechanical stores inventory. The cost of the centrifugal unit has not changed a bit. It is the same machine, repaired by replacing an integral part. The same can be said of the bowl or case of the above centrifugal. A centrifugal might have spare bowls, but only one bowl can be used on a centrifugal at any time, so the centrifugal unit can logically contain only one bowl. The extra bowl is an inventory item, just the same as an extra spark plug for a gasoline motor is an inventory item.

To restate the case, the unit of the centrifugal should include the cost of the bowl, case, shaft, base, motor and possible accessories mentioned above. Replacements of any of the above parts is a repair charge and has no effect whatever on the capitalized investment structure. If a record is desired on motors, etc., it might be advantageous to assign and affix a number to the motor for physical control, but the capitalization of the motor should be included in the capitalization of the unit of which the motor is a part.

Another problem presents itself with regard to the definition of this word "accessories." To follow through with our centrifugal example, let us assume that there are interchangeable bowls. One bowl is steel and the other is rubber-covered, each for use with various products. Since the second bowl increases the value of the machine to the plant, it should be capitalized. It becomes an accessory to the main centrifugal and should be so indicated on the detail asset card.

As another example, consider a caterpillar tractor with equipment. The unit of the tractor includes motor, housing, cab, tracks and accessories. In this case, two accessories are purchased: a high-lift bucket and a bull-dozer blade. Both of these attach to the front arms of the tractor. Only one of these items can be used at a time, but each enhances the value of the tractor unit to the plant. These parts should be charged to the tractor detail card as accessories and described as such. Extra bull-dozer blades or buckets of the same design are inventory items.

To summarize the above, the following definitions might be given.

Unit—An operable piece of equipment

including all pertinent parts to make it so.

Operable—Capable of being used for the purpose for which it was intended.

Accessory—Any item purchased for a unit which increases its value to the plant. It makes the unit adaptable to an additional purpose.

It is in the sense of the foregoing definitions that it is here recommended that an operable piece of equipment be regarded as a unit of property and the dividing line between replacement and repair made accordingly.

G. T. POMEROY, *St. Louis Chapter*

ACCOUNTING MANUALS—THE GRADUAL BUILDUP METHOD

Editor, N.A.C.A. Bulletin:

ACCOUNTANTS WHO USE ACCOUNTING MANUALS in their organizations' various operating divisions will agree that they can be exceedingly useful as a means of enhancing understanding and appreciation of problems involved, by operating personnel The manuals may be of the "how to do it" or "what to do" types, or they may be a combination of these two forms. Too frequently, however, the formidable prospect of starting from scratch and issuing and maintaining an accounting manual, discourages the development of really needed manuals. But accounting manuals need not be a problem!

This narration relates to an experience in the manufacturing and research departments of an integrated oil company on the Pacific Coast. The company has two large refineries and four small ones. The financial and payroll accounting is done in the home office. All refineries and the research field offices supply the home office with source data—time sheets and other payroll forms, warehouse withdrawal records, requisitions, approved invoices, etc. There is a great variety of transactions for which there is needed a permanent reference for guidance as to what is to be done and how to do it. Before a manual existed, the guiding instructions had been in the form of regular correspondence. Locating references required search of files. The volume of such references made the files an awkward informational source for all concerned. After a few years had elapsed, certain correspondence had a strange way of disappearing.

Several years ago, a relatively painless method of building up an informal accounting manual was devised. It entailed none of the tremendous effort required to originate a complete manual and it could be maintained on an up-to-date basis with relative ease. The idea was simply an extension or expansion of the existing practice of issuing accounting instructions by correspondence.

It was decided that all letters covering accounting instructions would be issued with the regular applicable file number and marked "Manual." In addition, an index system was evolved through which the alphabetical section in which the letter was to be filed would be given under the word "Manual." For instance, if the accounting instructions had to do with handling of catalyst, the symbol "C-4" might be assigned to indicate that it was to be filed under "C" in group "4." If the accounting instructions were about sales tax refunds, then the letter "T-17" might be used to show the alphabetical grouping for such subject. Thus, the same indexing principle would be used throughout the manual, which consists of a 3-ring binder and its contents. From the inception of this plan, the master manual grew from one binder to six binders, with two to four in the field offices, and there is a fairly adequate coverage of most of the accounting problems.

Accounting personnel used the manual from the outset. However, with the passage of time and an increased awareness

of the value of such a manual in its completed form, many additional sets were requested by operating supervisors to complete their understanding of procedures and to serve as a reference in connection with problems having to do with accounting for their departmental operations. The sense of need which has been developed for the manual in its present form is strong and the fact that it is indexed in binders instead of correspondence files and that, whenever practicable, the reason for the instructions is given, has apparently made the difference between its being a pronounced success or just another letter.

Revisions are issued with the same file number and index number as appeared on the prior letter and, immediately below, is noted the word, "Revised" with date. If minor changes are made, a letter of transmittal is sent pointing them out to minimize interpreting time. If the changes are major, there is no point in separately mentioning the changes because it would be necessary to read the full instructions. As an adjunct to the foregoing, a separate correspondence file control is kept for all manual letters by the file clerk, on a sheet having headings: accounting division number, manual index number, date, letter file number, and subject. All manual letters issued are logged in this control and each revision dated.

This method of building up a complete manual may seem a long-drawn-out process. It did take a number of years to bring it up to its present basis. However, in the slow development, many opportunities were found to improve its content and to extend its use. This manual is now so well established that it is a solid part of the accounting contact and control. It has so gained in value in the minds of its holders that it is apparently considered indispensable. In looking back over the years in which the manual was developed, it is apparent that it has made the administration of accounting policies materially more effective, has secured participation of operating people (a noteworthy accomplishment), and has given the field offices and home office a pronounced sense of reliance and understanding in connection with accounting procedures.

L. L. SWEET, *Los Angeles Chapter*

A "TAG AND CARD" SYSTEM OF ACCOUNTING FOR RETURNABLE CONTAINERS

Editor, N.A.C.A. Bulletin:

ACCOUNTING FOR RETURNABLE CONTAINERS has been described very adequately as "essentially a necessary nuisance" (letter by William E. Lunay, *N. A. C. A. Bulletin*, February 1953). The problem could be eased to a great degree by the various vendors who ship materials in such containers, if they would simply adapt a standardized method of charging container deposits and demurrage. However, since the standardized method does not appear to be forthcoming, the vendee must set up a workable procedure for handling and accounting for the containers.

As a vendee of material received in returnable cylinders, drums, and carboys we have built up such a procedure. While the method was designed for the engineering laboratory of a large electrical manufacturer, it should be applicable to any manufacturer. The laboratory consists of several engineering departments, each with its own production service unit, plus a general service department. Several different materials are used which are received in various types of returnable containers from a number of different vendors.

The procedure developed has resulted in the efficient handling and accounting for the containers with a considerable time saving in both the handling and paperwork. It is designed to fit into the organizational

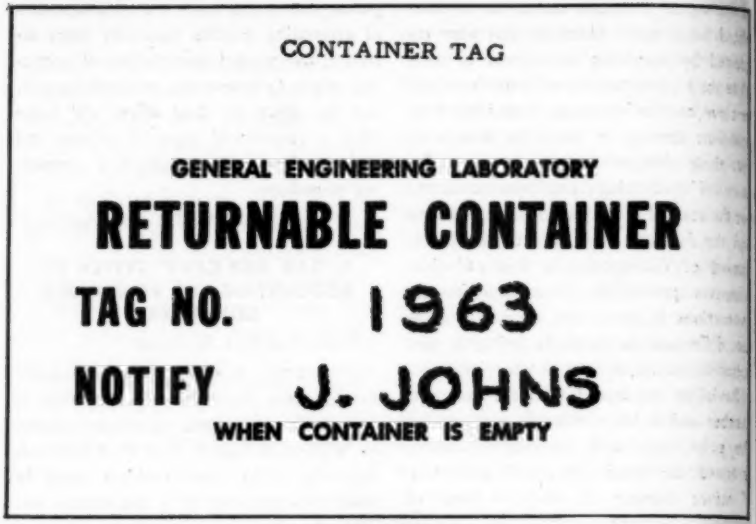


EXHIBIT 1

structure of the laboratory and centers around two forms. One is an adhesive backed cloth tag (Exhibit 1) which is fastened on the container. It is weather-resistant and adheres strongly to the container. It is also legible, even after lengthy outside storage and will withstand considerable handling. The second is a card (Exhibit 2) made up in duplicate, which is used to follow and account for the container. The cards are serially numbered and are purchased as a two-part form, with carbon interleaved, so that both copies are prepared with one writing.

When a container is received, the receiving section inserts the following information:

1. *On the tag*
   a. Serial number of the card.
   b. Production supervisor responsible for the material.
2. *On the card*
   a. Vendor's name.
   b. Serial number (for cylinders only).
   c. Date received.
   d. Type of material.
   e. Purchase order number.
   f. Job order number for which material was ordered.
   g. Location to which the container is to be delivered.

The tag is then fastened to the container in a prominent place and the original card is forwarded to the clerk in the accounting department who, among other duties, is responsible for the accounting for returnable containers. The duplicate card is forwarded to the production supervisor responsible for following the material. In the accounting department, the cards are filed alphabetically by vendor and, also, in the case of cylinders, are further segregated by serial number of container. In the production units, the cards are filed by card number.

Invoices received for material purchased in returnable containers are forwarded to the returnable containers clerk in the ac-

CONTAINER CARD

Nº 1963 Vendor XYZ Co. Serial No. FF 760

Date Rec'd 3-4-53 Demurrage Date 4-4-53

Invoice No. 3251 Date 3-2-53 Type ARGON

PDGL 28278-11 S.O. 086-652-9601

Cost 28.00 Delivered to 276-B # 37

RETURNED

PDGL 28278-11 S.N. 32323 Date 3-25-53

Credit Memo 1111 Date 4-2-53 Amount 28.00

Return Authorized by John Johns

EXHIBIT 2

counting department who notes on his card: (1) the invoice number, (2) invoice date, (3) the demurrage date and (4) the amount of deposit. The invoice is then initialed by this clerk and forwarded to the accounts payable section for payment. In this way the information called for by the card is completed. This procedure also acts as a check to determine that all containers received and billed to us have been tagged. The deposit on the containers is then charged to the returnable containers account and the cost of the material and drayage is charged to the job to which it applies.

When the container is ready for return to the vendor, the production supervisor responsible for it signs his name to the production unit's copy of the returnable containers card as authorization for the container's return, and forwards the card to the purchasing department. The purchasing department then notifies the vendor that the container is being returned. From the information on the card, the purchasing department has complete information necessary to effect the return and is responsible for initiating a request to the shipping department with a copy to production to have the containers shipped to the vendor.

The shipping department makes out the necessary serially-numbered shipping papers and ships the container back to the vendor without delay. The particular container can be identified easily by the container tag, for matching with the shipping papers. Copies of the shipping papers are forwarded to the accounting, purchasing and production departments to complete their records of the transaction.

The accounting department's returnable container clerk, on receipt of his copy of the shipping papers, removes his container card from his open files and attaches it to the shipping papers. A debit memo is then issued to cover the costs chargeable to the vendor. The returnable container's account is relieved of the deposit and a receivable account charged. When the vendor's check is received or the amount is deducted from

the next payment to them, the receivable account is then credited.

In addition to the above, separate records are maintained for cylinders on which a deposit is not charged but upon which demurrage charges may be incurred. This is a simple stock record card showing receipts and shipments, with the applicable purchase order and shipping paper numbers so that monthly invoices covering demurrage charges can easily be checked and passed for payment by our returnable containers clerk.

To aid the operating departments to effect prompt return of all containers, the accounting department issues periodic reports to the management of each operating department listing the containers on hand in each department, with a request that a thorough review be made to determine which containers can be returned.

Once a year, a complete physical inventory is taken, at which time both the inventory cards and containers' cards are cross-referenced. The cost of each container which cannot be located during a physical inventory, is charged to the responsible operating department's overhead and the returnable containers' account relieved. Accordingly the returnable containers' account balance can be verified at any time through the returnable containers card file.

In our organization we have found that the above procedure has worked very effectively and with minimum cost of handling this "necessary nuisance."

HARRISON C. LELAND, *Albany Chapter*

SHOULD INVENTORY AND COMMITMENT CONTROL BE A CLERICAL OR AN EXECUTIVE FUNCTION?

Editor, N.A.C.A. Bulletin:

FREQUENTLY MERCHANDISING AND MANUFACTURING ORGANIZATIONS have found it desirable to create an inventory control activity in the accounting department for the purpose of maintaining continuous inventory controls and reconciliations. Unfortunately under many such plans of centralizing inventory responsibilities, the work is considered to be merely a clerical function. The only recognized benefits may be that other sections of the accounting or material control departments responsible for receiving, shipping or inventory records, may be relieved of the task of reconciling figures against the inventory control accounts maintained for general accounting purposes.

For cost accounting purposes individual records by products, in terms of both physical units and dollars, are usually maintained. This procedure also has the advantage of eliminating unit values from stock room or bin card records which should be maintained to control quantities only. Personnel of the permanent inventory control group should have the responsibility of continuously checking raw materials, purchased parts and supply materials in the stores cribs and operating departments by physical count and proving the actual counts of items against bin cards and other physical inventory records and reconciling such records with the accounting controlling accounts. However, such reconciliations to be effective should become a part of a program of continuous review and audit at regular intervals, preferably on a monthly basis.

Experience has proven that this procedure will eliminate any substantial inventory adjustments at the end of a fiscal year, by making it possible to absorb into the cost of production and current operations any charges represented by material losses, either normal or abnormal, as they occur.

It may also be desirable to enlarge the program of inventory control beyond the routine clerical aspects as outlined above so that both commitment and inventory con-

trol functions may be coordinated under a single unit to assist the controller in his larger responsibilities as follows:

1. Establish financial limits of expenditures, in accordance with corporation policies and conditions of specific contracts.
2. Negotiate and finalize, in collaboration with the general manager, contracts committing the operation to specific delivery schedules and sales programs.
3. Accumulate figures and prepare necessary statistical charts, reports and other data for financial, inventory and commitment control purposes.
4. Make audits when and where necessary to determine the propriety of inventories in relation to production and sales activities and purchase commitments.
5. Provide data to effect cancellation of orders and proper disposals and recommend terms of settlement of claims with vendors and government agencies.

The benefits of proper control and valuation of inventories and the systematic coordination of such activities with the function of commitment control from the standpoint of good administration and accounting are many. The advantages include, as factors of major importance under present conditions, the following:

1. ***Balance sheet valuation and classification***—Facilitate the preparation of financial statements, budgets, and forecasts of production and sales.
2. ***Determining cost of sales***—Obtain correct valuations of inventory for operating statements, thus assuring that production and sales has been charged with all materials used or shipped.
3. ***Internal audit control***—Determine variations from standard costs and the control of obsolescence, waste, leakage, salvage, and fraud.
4. ***Defense contracts, terminations, and renegotiation***—Establish division of cost between complete and incomplete units of production for price redetermination, cancellation settlements and verification of cost allocations and increment in value of exempt raw materials for renegotiation.

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